Seafood Watch
Seafood Report

MONTEREY BAY AQUARIUM®

Farmed U.S. Freshwater Coho Salmon
Oncorhynchus kisutch

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About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch®'s sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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I. Executive Summary

This report details the U.S. production of coho salmon in inland freshwater tank-based farms, a significantly different production system from the almost ubiquitous marine net pen salmon farming model. Production of salmon in freshwater is currently small in scale and volume, and limited to a few species. However, freshwater farmed salmon has the potential to provide an alternative product to salmon raised in marine net pens that are currently ranked ‘Avoid’ according to Seafood Watch criteria.

The recommendation presented here is based on the specific example of Domsea Farms, owned by AquaSeed Corporation in Washington State, which is currently the sole U.S. commercial producer of inland, tank-based coho salmon. The specific production systems and ecological contexts of individual farms may vary as the industry develops. Therefore, this Seafood Watch ranking only applies to the current U.S. freshwater coho industry and will be updated and reevaluated as production practices develop and the industry expands. Similar freshwater production systems are used in Canada for coho and sockeye salmon, but are not assessed in this report due to their small production volumes and different regulatory requirements.

The presence of physical barriers in tank-based aquaculture limits interaction between the cultured fish and the external environment. These systems are considered ‘closed’ in this respect according to popular definitions even though effluent must still be discharged from tanks and the potential for impacts to wild fish and ecosystems is not eliminated. Therefore, where relevant to specific Seafood Watch criteria, these systems will be still be considered ‘open’ in this report. While different combinations of flow-through and recirculating water systems are currently used to produce freshwater coho salmon, the current Seafood Watch ranking takes a precautionary approach by considering only flow-through production, as this is associated with the highest risk of environmental impact.

Like all salmon farming systems, freshwater coho salmon uses marine feed ingredients in the form of fishmeal and oil derived from wild-caught fish. In some cases, these are replaced to a certain extent by plant-based ingredients and fish processing by-products. The calculated wild fish input to farmed fish output ratio (WI:FO) for freshwater coho is 1.2:1, resulting in a ‘Moderate’ ranking for the use of marine resources. Calculated from a combination of global salmon data and farm-specific feed formulation data, this ratio is relatively low for farmed salmon and represents the use of fish processing by-products and other alternatives to marine feed ingredients.

Although Seafood Watch considers escapes to be inevitable from most farming systems, inland tank-based systems allow for the placement of effective barriers. Escapes from such systems are considered to be infrequent. This conclusion is supported by independent monitoring data from the Washington State Department of Fish and Wildlife, verifying that escapees have not been recorded from this particular farm. It is unlikely that escaping fish would affect populations of endangered, threatened or protected wild stocks, but supporting data are insufficient. As a precaution, the stock status of potentially affected fish is deemed at ‘Moderate’ risk. Overall, the risk of escapes is determined to be a ‘Low’ conservation concern.

The nature of flow-through aquaculture poses an inevitable risk of spreading disease to wild stocks. Precautions have been implemented at the Domsea Farms freshwater coho facility to mitigate this risk. Biosecurity protocols maintain low rates of disease in the farmed population. Bacterial Kidney Disease (BKD) is considered the greatest threat. Conditions specific to the current operations allow them to operate with little risk of introducing disease. These conditions include use of a pathogen-free water source, no shared equipment (eliminates cross-contamination from other farms), and adherence to a fish health protocol (including continual disease monitoring by fish health experts). Mandated disease monitoring shows current management practices to be effective in controlling amplification. It is likely that the potential to impact endangered, threatened or protected wild stocks is low, but as supporting data are insufficient, this factor is determined to be a ‘Moderate’ risk. Overall, amplification and retransmission of disease, and the introduction of new diseases is determined to be a ‘Low’ conservation concern.

Tank-based systems enable treatment of effluent water to remove wastes or pollutants before discharge. Effluent passes from grow-out tanks through settling ponds before discharge, and it is monitored to ensure compliance with U.S. regulatory standards for nutrient pollution. Although the local and regional effects of effluent are unknown, monitoring data show compliance with regulatory limits and demonstrate that only low levels of nutrient pollution leave the farm. Pollution and habitat damage are therefore considered to be a ‘Low’ conservation concern. Increasing use of recirculation systems offers the opportunity to further reduce effluent concentrations.

The complex U.S. regulatory structure for aquaculture covers a number of issues related to siting, discharge of waste and risk due to escape and disease. Domsea Farms currently complies with applicable laws through appropriate permits for transport and effluent discharge as well as through ongoing disease monitoring. While it is unclear whether current policies would support sustainable development of the industry as it expands, the management regime for this farming system was determined to be of ‘Low’ conservation concern at the time of this writing.

Therefore, overall, U.S. production of freshwater coho salmon in inland locations is considered a ‘Best Choice’.

Nevertheless, Seafood Watch recognizes this type of aquaculture is still in its infancy. For the purposes of continued improvement and to help maintain a ‘Best Choice’ ranking as the industry grows, we recommend conversion to fully closed recirculating systems, further reduction of marine resources in feeds, improvements in disease control and increases in energy efficiency.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Use of Marine Resources		√		
Risk of Escaped Fish to Wild Stocks	√			
Risk of Disease and Parasite Transfer to Wild Stocks	√			
Risk of Pollution and Habitat Effects	√			
Management Effectiveness	√			

About the Overall Seafood Recommendation:

- A species receives a recommendation of "**Best Choice**" if:
  1) It has three or more green criteria and the remaining criteria are not red.
- A species receives a recommendation of "**Good Alternative**" if:
  1) Criteria "average" to yellow

  2) There are four green criteria and one red criterion.
- A species receives a recommendation of "**Avoid**" if:
  1) It has a total of two or more red criteria

  2) It has one or more Critical Conservation Concerns.

Overall Seafood Recommendation

Best Choice ✔ Good Alternative Avoid

II. Introduction

Biology

Coho salmon (*Oncorhynchus kisutch*), also known as silver salmon, is a Pacific salmon belonging to the family Salmonidae (NMFS 2009b). Like all Pacific salmon, the coho is naturally anadromous: born in freshwater but destined to live its adult life at sea and return to freshwater to spawn. Generally, salmon spawn in the rivers and lakes of their birth and do so in different seasonal runs identified by the time of re-entry into freshwater. Pacific salmon are unusual in that most species are semelparous, spawning only once in their lives and subsequently dying, their carcasses transferring marine nutrients to freshwater spawning grounds (PSMFC 2006, USFWS 2009). Coho salmon can grow up to two feet (61 cm) in length and can weigh up to 36 pounds (16 kg), although average weight is about eight pounds (3.6 kg) (USFWS 2009). They are characterized by dark metallic blue or greenish coloring on their backs with silver along their sides, lighter hues on the belly and small black spots on the back and upper lobe of the tail while in the ocean. The lower jaw gumline of coho is slightly lighter in pigment than the upper, which differentiates them from Chinook salmon. When spawning in inland rivers, the skin of male coho darkens to a reddish-maroon color on both sides (Fig. 1).

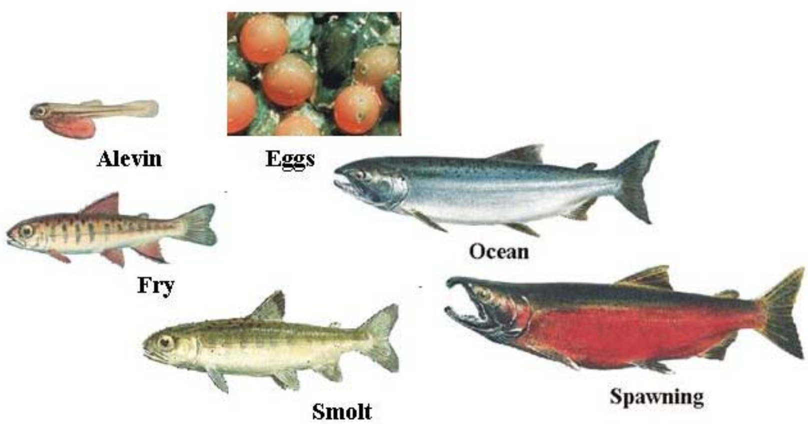

Figure 1. Appearance of coho at different life stages: eggs, alevin, fry, smolt and adults in the ocean and upon return to their native river for spawning (Images from Harry Heine, USFWS 2009).

In the wild, coho salmon spend approximately the first half (approximately 15 months) of their life cycle in streams and small freshwater tributaries growing from eggs to young fry (alevins) to juveniles (fry and smolts) (Fig. 1). The remainder of their life cycle (approximately 18 months) in the wild is spent foraging in estuarine and marine waters of the Pacific Ocean (USFWS 2009). While living in freshwater, coho feed on zooplankton (Wydoski and Whitney 2003) and insects. Coho fry have vertical marks along their sides for camouflage. These parr marks are lost as they transform into smolts and develop darker back and lighter belly colors for migration to the sea. Gills and kidneys also begin to change at this time, enabling the fish to process salt water. As adults in the ocean, coho subsist on a diet of small fishes (Sandercock 1991, ADFG 2007).

Conservation status

Coho salmon originally inhabited rivers, estuaries and marine environments throughout the North Pacific Ocean from central California to Point Hope, Alaska, throughout the Aleutian Islands, and from Russia to Japan (Sandercock 1991, USFWS 2009). Some populations, now considered extinct, are believed to have migrated hundreds of miles inland to spawn in tributaries of the upper Columbia River in Washington state, and the Snake River in Idaho (USFWS 2009). Wild Chinook and coho populations have experienced dramatic declines in abundance during the past several decades. A variety of anthropogenic and natural factors are implicated, such as alterations in fish community structures, the effects of water storage, withdrawal, conveyance, and diversion for agriculture, flood control measures, changes in stream water temperatures, reduced water quality, destruction of spawning and rearing habitat, and reduced food supply (NMFS 2009b). The status of Pacific salmon populations is evaluated in the Pacific Salmon Seafood Watch Report[1].

Pacific salmon are now one of the most intensively monitored and managed groups of fish on the planet. Given their commercial importance as well as their status as ‘threatened’ or ‘species of concern’ under the Endangered Species Act (ESA), considerable attention is currently devoted to stock abundance (NMFS 2009b). The species are managed by a variety of agencies including state and tribal governments, the Pacific Fishery Management Council (PFMC), the National Marine Fisheries Service (NMFS), the North Pacific Anadromous Fish Commission, and the U.S.-Canadian Pacific Salmon Commission. The commercial salmon fisheries from northern Oregon to the Mexico border have been closed by the Pacific Fishery Management Council (PFMC) since 2008 due to an unprecedented collapse of the Sacramento River fall Chinook and the poor status of Oregon coast coho (PFMC 2009).

Freshwater coho salmon farming methods

Salmonids such as salmon, trout and char are farmed in a variety of production systems including ponds, raceways, land-based tanks, net pens in freshwater lakes, and net pens in open coastal waters. The ‘open’ nature of net pens offers little ability to control water movement or quality. In contrast, ponds, raceways and tanks offer a physical barrier between the farm and the environment, and the ability to treat wastewater before release into the surrounding environment.

The Coastal Alliance for Aquaculture Reform (CAAR) defines closed system aquaculture (CSA) as ‘Any system of fish production that creates a controlled interface between the culture (fish) and the natural environment’(CAAR 2008). A closed system in this sense does not have total control over its interactions with the surrounding environment, but rather some greater degree of control when compared to an open system. Production systems defined as ‘closed’ can include ponds, tanks and raceways run on single-pass flow-through systems. With increasing complexity, tank systems may also run as recirculating systems, treating and re-using a portion of the water up to nearly 100%. Thus, by this definition, the systems evaluated in this report are considered to

[1] The Seafood Watch Pacific Salmon report is available online at: www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_SalmonWildReport.pdf

be ‘closed’. Effluent is still discharged into the environment to varying degrees, and therefore it remains important to consider the associated ongoing environmental risks such as nutrient losses and their impacts, potential transmission of pathogens and parasites, and the escape of farmed fish.

Due to the anadromous life cycle of wild salmon, the typical salmon farming production model includes a marine growing phase in coastal net pens where the bulk of the growth takes place. However, landlocked populations of several typically anadromous salmonid species occur naturally. Through selective breeding and domestication over many generations of a specific strain of coho salmon, it has become possible to manage the complete life cycle (from egg to juvenile to spawning adult and back to egg) in freshwater only. Therefore, it is possible to farm salmon in inland locations in relatively contained freshwater production systems. This report focuses on the production of coho salmon in such ‘closed’ systems operating on a flow-through or recirculating basis.

CAAR (2008) describes the strengths of closed-system aquaculture as:

- Potential to control growing conditions including temperature, water chemistry and turbidity, disease, etc.
- Stress reduction through control of predation, disease and growing conditions (no temperature or water chemistry fluctuations).
- Potential to influence growth cycles including time to harvest, size of the species, quality of product, feed consumption, and metabolic rates, as well as optimum harvest points and the ability to plan for harvest.
- Better Feed Conversion Ratios (FCR) due to greater control over growing conditions, life cycles and water movement. This means less feed is lost and the nutrient content of effluent is minimized.
- Greater versatility—options for production location, proximity to market, marginal lands use, etc.; production can be tailored to take advantage of local conditions such as water temperature, water quality and skilled labor; ability to respond to demographic and consumer shifts (some systems are capable of growing different species or can be easily transformed); and the potential for enhancing technology.
- Control of outputs and effluents—treatment and the possibility of reuse as fertilizer or input for other fish systems (in integrated aquaculture).
- Risk reduction—including climate, infection and disease, predation, etc.
- Reduction in certain direct operational costs associated with feed and disease control from vaccinations and antibiotics.

- Potential for a ‘clean product’ produced without hormones, antibiotics, etc., in an environmentally friendly way amenable to green and organic labeling.
- Longer average life of tanks and equipment (versus nets) allowing for longer amortization periods.

The general challenges are:

- Increase in capital costs—research and development can be costly; system start-up cost is greater than for net pen operations.
- Increase in certain direct operational costs—usually higher costs are associated with inputs such as oxygen and the maintenance costs associated with balancing the water chemistry (although some flow-through systems based on groundwater sources don’t require any inputs or water treatment), careful water monitoring, energy requirements (depending on the technology), input-output water treatment requirements (associated with high-density farming).
- Complexity of technology, particularly with regards to maintaining the water environment and with the use of biofilters in recirculating aquaculture systems.
- Risks including the potential for rapid chemistry alterations and dependency on monitoring (increases with greater fish densities) (CAAR 2008).

The substantial need for material and energy inputs associated with this type of production system has been a key point of criticism. These systems use technology to counteract many environmental problems, yet they contribute to other environmental impacts of global concern. Ayer and Tyedmers (2009) pointed out that these may include climate change, non-renewable resource depletion and ocean acidification, all of which are largely related to increased energy and freshwater use, creating an apparent trade-off between environmental impacts. Addressing energy concerns through greater efficiency or conversion to renewable sources seems feasible, and more options appear available to address this environmental problem than those created by open cage aquaculture. However, evaluation of terrestrial resource and energy use by aquaculture operations is beyond the scope of the current Seafood Watch criteria.

This report focuses on the sole commercial producer at the time of writing, Domsea Farms owned by AquaSeed Corporation, as a representative example of the industry. The recommendation is based on this farm and the U.S. federal regulations that apply to this type of aquaculture operation. Domsea Farms is a vertically integrated freshwater coho salmon farm producing 50–100 tons of freshwater live weight coho salmon per year in western Washington state. It shares a site and water source with its associated hatchery, Domsea Broodstock, also owned by AquaSeed Corporation. A farm and hatchery formerly operated at the same site under the name Swecker Salmon Farm (EPA 2004). Domsea Broodstock raises salmon eggs for Domsea Farms, for sale to other aquaculture operations and for stock enhancement in Lake Oroville, California.

Figure 2. Grow-out tank at AquaSeed's Domsea Farms (Photo by G. Shester, Monterey Bay Aquarium).

The Domsea® pedigree strains (odd and even year) of coho salmon raised for food fish production originated from Skykomish River coho in Washington state. The Domsea coho has been bred for over 16 generations since 1977. Beginning in 1986, the Domsea broodstock has been cultivated in freshwater through the entire life cycle (Neely *et al.* 2008), creating the first generation of land-based freshwater-bred coho salmon. The stock has also been selected for the best energy utilization and feed efficiency to promote rapid growth (Myers *et al.* 2004, Neely *et al.* 2008). The Domsea coho salmon raised at Domsea Farms to produce SweetSpring brand coho have a two-year life cycle, large body weight and high smolt survival in the first year of life (Tave 1989). According to Mr. Per Heggelund, owner of AquaSeed Corporation, Domsea coho salmon is harvested at two size classes: 650 grams and 1.4 kilograms (live weight) to produce SweetSpring fillets of 5 oz and 12 oz, respectively (P. Heggelund 2009, pers comm.).

Stock density is kept at typical levels compared to similar production systems, although these levels are quite high compared to typical open-water cage salmon farms. According to Mr. Greg Hudson, a Vice President of Production for AquaSeed and manager of both Domsea Farms and the Domsea Broodstock hatchery, the Domsea broodstock is maintained at approximately 16 kg/m^3, although this may increase to 48 kg/m^3 at times (G. Hudson 2009, pers comm.). Domsea Farms reports densities between 35 and 40 kg/m^3 in their grow-out tanks (P. Heggelund 2009, pers comm.).

The primary inputs to the grow-out tanks are feed, well-water sourced from the site, salt and calcium chloride, which are generally used in soft-water hatcheries to increase the water hardness without significantly increasing the salinity of the water (Mazik *et al.* 1991). All waste from the grow-out and hatchery tanks exits via gravity flow into a series of settling ponds separated by pipes with small holes, cages and grates (Fig. 5). The settling ponds serve to treat the effluent, allowing suspended solids to settle to the bottom of the pond for subsequent removal and use as fertilizer on nearby farms. Effluent outfalls discharge from the settling ponds through a pond drain pipe into a wetland bordering the Black River (Fig. 3) (EPA 2004). Rate of waterflow from the wetland over the river bank fluctuates, depending on season, weather, and rate of flow leaving the farm (EPA 2004, USGS 2008). Mr. John Kerwin, the Conservation Biology Unit Leader of the Fish Program for the Washington Department of Fish and Wildlife (WDFW) verified that the Black River drains into the Chehalis River system (J. Kerwin 2009, pers comm.).

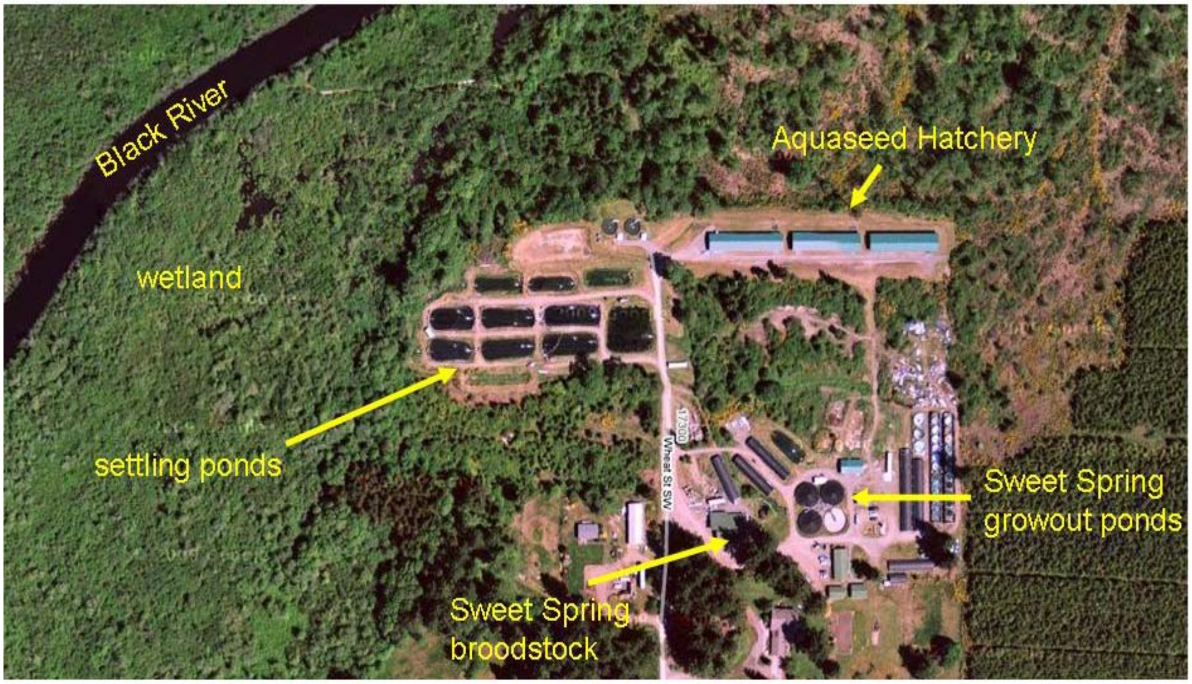

Figure 3. Schematic diagram of the Domsea Broodstock coho salmon farm in Rochester, Washington showing farm layout and proximity of settling ponds to the wetland and the Black River. This photo was taken before the construction of several new grow-out tanks (map from Google Maps).

The farm is classified as a flow-through system in this report. The broodstock and hatchery are operated in single-pass flow-through systems and the grow-out tanks reuse 85–98% of their water. By definition, this is a 'closed' system, and this farm is able to exert a high level of control over certain factors affecting the surrounding environment (CAAR 2008). The tank containment situation reduces to the possibility of escapes, for example. However, this system is not fully disconnected from the environment. A significant volume of effluent leaves the farm as water flows through the tanks and settling basins. Thus, this aquaculture system has contact with the environment and the potential to exert negative effects on nearby fish populations and their habitats.

The farm utilizes components standard for all recirculating systems: mechanical filters to remove large particulate wastes, biological filters to break down soluble nitrogenous wastes, foam fractionators (or protein skimmers) to remove other soluble and partially soluble compounds, sterilizers to control bacterial levels (e.g., ultraviolet light or ozone), aeration or oxygenation to reduce carbon dioxide and increase oxygen, and heaters or coolers to maintain water temperature. Effluent is typically released post-treatment and may be subjected to secondary treatment before release.

Global farmed coho salmon production

Culture of coho salmon began as a means to enhance commercial fisheries in Oregon at the turn of the twentieth century (Fairgrieve 2006). Production continued for many decades producing negligible yields in marine net pens until the National Marine Fisheries Service spurred commercial coho culture into action in 1969. Sea cage production systems were introduced at this time in Washington's Puget Sound. Production using this system grew and by the 1980's, the region was yielding over 3,000 tons of coho in floating cages per year (Fairgrieve 2006). The industry expanded globally at this time into Chile and then Japan. By the 1990's, these two countries owned most of the burgeoning farmed coho market. Worldwide production increased from around one ton to 7,000 tons between 1981 and 1991, and surpassed 90,000 tons in 2000. Global coho production has declined considerably since then in favor of rainbow trout and Atlantic salmon. Chile remains the primary producer, with about 89% of the total global production of 115,376 tons in 2007 (FAO 2009). Other current major producers are Japan and Canada.

U.S. freshwater production of coho salmon in flow-through and recirculating systems presently constitutes only a small portion of global farmed coho production and the broader global farmed salmon industry. There are only a few commercial operations worldwide, including Swift Aquaculture in Agassiz, British Columbia, Canada; AquaSeed Corporation and Domsea Farms in Rochester, Washington; and Blue Ridge Aquaculture experimentally producing Atlantic salmon in a reduced salinity tanks in Logan, West Virginia (CAAR 2008, Blue Ridge 2009).

Scope of the analysis and the ensuing recommendation

This Seafood Watch report assesses freshwater coho salmon farming and production in inland tanks in the United States. As the sole commercial U.S. producer using this type of operation, the recommendation is based largely on the specific example of Domsea Farms and the U.S. federal regulations that apply to this type of aquaculture operation. Hence, the resulting recommendation applies to all farmed coho salmon produced in the U.S. in similar systems and ecological contexts. Domsea Farms uses both flow-through and partially recirculating water management systems and plans to fully 'close' its operations in the future using a fully recirculating system with minimal discharge. However, the bulk of production is currently based on flow-through methods, and as it is associated with a higher risk of environmental impact, the Seafood Watch ranking is based on this system. As the industry expands into new areas and additional information becomes available regarding this new type of aquaculture, this report and its recommendations will be updated and reevaluated.

Availability of science

Compared to other aquaculture systems such as marine cultivation of salmon and freshwater production of trout, there is limited peer-reviewed information concerning the cultivation of freshwater coho in inland tanks. At the production level, Domsea Farms in Washington state was used as the primary basis for this assessment; much of the information having been verified through third party laboratories, feed manufacturers, and government agencies monitoring the farm. In addition, Seafood Watch staff visited the operation in May 2009 to observe the operations, gather initial information and take photographs. All information provided directly by Domsea Farms that is relevant to the Seafood Watch evaluation criteria has been independently verified either through direct observation or through communication with government regulators. In addition, Seafood Watch reports on farmed Arctic char and farmed rainbow trout contain analyses of similar production methods. As the prevalence of freshwater coho production increases, it is likely that a larger body of scientific information will become available.

Market availability

Common names for *Oncorhynchus kisutch* are coho salmon and silver salmon. Coho salmon from freshwater recirculating tanks is available year-round under the SweetSpring brand. As of the writing of this report, the product is sold in pre-packaged 5 and 12 ounce fillets either unseasoned, with herb and spice ‘rubs’ or on cedar planks (Fig. 4). Other product forms are currently being explored. Current annual commercial production is estimated to be 50–100 tons live weight.

Figure 4. SweetSpring products currently available on the market (Photo by G. Shester, Monterey Bay Aquarium).

III. Analysis of Seafood Watch® Sustainability Criteria for Farmed Species

Criterion 1: Use of Marine Resources

Guiding principle: *To conserve ocean resources and provide net protein gains for society, aquaculture operations should use less wild-caught fish (in the form of fishmeal and fish oil) than they produce in the form of edible marine fish protein.*

Historically, aquaculture has added to global seafood supplies by creating a gain in net protein. However, current trends favoring the farming of carnivorous species that require high inputs of protein relative to the amount produced have effectively reversed this gain (Naylor *et al.* 2000, Naylor *et al.* 2009). About 33% of the world's wild-caught fish is converted to fishmeal and fish oil for aquaculture feeds in the form of pelleted or compound feeds (Tacon and Metian 2008). The amount of compound feed required to meet nutritional requirements varies among species and production methods. Farming carnivores that are high on the food chain, such as salmon, although directly efficient in converting their feed to flesh, are relatively inefficient overall in terms of marine resource use because volume for volume, more wild-caught fish is put into the farm as feed than fish is produced as food.

Reduction fisheries (a.k.a. 'industrial' or 'forage' fisheries) are those in which the wild harvest is "reduced" to fishmeal and fish oil as the basis for agricultural and aquacultural feeds. They are typically comprised of small bony pelagic fish, some of which are managed better than others (SOFIA 2007, NMFS 2009a). While terrestrial agriculture (e.g., poultry, swine) contributes to the exploitation of wild-caught fish for feed, aquaculture is placing an increasing demand on these resources. Aquaculture is one of the fastest expanding sectors of global food production, and the use of feed for aquaculture ('aquafeeds') follows suit. It is predicted that the dependence of aquafeed on forage fisheries will expand in the future as the entire sector expands (Tacon and Metian 2008), and modern aquaculture joins other industrial food systems that are "farming up the food web" (Pauly *et al.* 2005).

Exact sources of fishmeal and fish oil in forage fisheries can be difficult to determine due to the proprietary concerns of feed manufacturers. Nevertheless, we do know that most of those fisheries are for small pelagic species such as anchoveta, Chilean jack mackerel, Atlantic herring, chub mackerel, Japanese anchovy, sardines, Atlantic mackerel and European anchovy (Naylor *et al.* 2000). These species mature quickly, reproduce prolifically, are low on the food chain and are preyed on by higher trophic level animals such as piscivorous fish, seabirds and marine mammals. Forage species play a crucial role in marine ecosystems as they transfer energy from plankton up the food chain (Naylor *et al.* 2000, Alder and Pauly 2006, MATF 2007). Their removal can have detrimental impacts on entire ecosystems (Baraff and Loughlin 2000, Tasker *et al.* 2000, Furness 2003, Goldburg and Naylor 2005, Walters *et al.* 2005, Becker and Beissinger 2006), including damage to populations of commercially important fish, other predatory fish, seabirds and marine mammals. While some fisheries are known to be well-managed (NMFS

2009), there are multiple sources of uncertainty regarding these species' population sizes. Consequently, the removal of forage species should be managed to err on the side of caution (NRC 2006). A healthy abundance of forage species in our coastal marine systems is critical to the resilience of these systems in the face of likely global climate and oceanographic changes in the coming decades (IPCC 2007).

Reducing pressure on marine resources begins with reducing reliance on forage fisheries. Farming herbivorous species is one solution. Mussels are an example of filter feeder that do not require farm-level inputs in order to raise a quality product. Decreasing the amount of fishmeal and fish oil in aquafeeds for carnivorous farmed species is another tactic. Wild fishmeal and fish oil are integral in the feed of many species to provide essential amino acids and fatty acids that cannot be obtained elsewhere. However, their use can be reduced and supplemented with alternatives (Tacon and Metian 2008) including plant-based proteins such as soy bean meal, barley, rice, peas, canola, lupine, wheat or corn gluten, algae and protein derived from fish or terrestrial livestock processing by-products. The use of plant proteins and rendered animal products in fish feeds is now widespread throughout the world. Average inclusion rates of marine products have steadily declined (Tacon and Metian 2008, Naylor *et al.* 2009), but complete elimination of fishmeal seems impossible at this time because of nutrient requirement profiles and digestive tolerances (Tacon 2005).

Potential trade-offs associated with substituting plant proteins for fishmeal and fish oil include changes in the composition, texture and taste of the fish, as well as human nutritional concerns. Fish oil provides linoleic and linolenic series essential fatty acids that are indispensible in fish diets since *de novo* synthesis does not take place and no commercial alternatives are currently available to reduce the need for fish oil in feed (Pillay and Kutty 2005). Replacing fatty acids with plant oils also lowers the levels of omega-3 fats that are beneficial in human diets (Johnston 2002, Naylor *et al.* 2009). Although research continues into alternative feeds, using wild fish inputs remains a major limitation in the future growth of a sustainable aquaculture industry. To achieve true sustainability, the industry must reduce its dependence on wild fish and other marine resources and find a balance between the needs of fish physiology, animal welfare, sustainability of the reduction/forage fisheries, human health needs and the preferences of the human palate.

Tacon and Metian's 2006 global survey of aquaculture feed manufacturers compiled invaluable information from the aquaculture industry regarding the use of fishmeal and fish oil, since much of the information collected is 'sensitive and proprietary in nature.' This paper remains the most reliable source of this information to date (Tacon and Metian 2008).

Salmon are highly carnivorous, requiring 40% crude protein in their diet (Pillay and Kutty 2005). In the wild, a varied diet of zooplankton, fish and insects provides this along with other nutrients. All farmed salmon are fed compound (pellet) feeds containing wild fishmeal and fish oil (Weber 2003, Tacon and Metian 2008).

Primary factor – WI:FO

To estimate the use of marine resources, Seafood Watch® calculates the ratio of wild fish inputs needed to produce the farmed fish output (WI:FO). This WI:FO estimate is equivalent to the 'fish conversion efficiency' described in the report *Sustainable Marine Aquaculture: Fulfilling the Promise; Managing the Risks* by the Marine Aquaculture Task Force (MATF (2007). This ratio evaluates how much wild fish (by weight) is used as feed to produce farmed fish. The WI:FO ratio is calculated by multiplying three separate measures:

- **Yield rate:** the amount of fishmeal or fish oil extracted from whole wild fish;
- **Inclusion rate**: the percentage of fishmeal and fish oil included in formulated feeds (calculated separately for fishmeal and fish oil); and
- **Feed conversion ratio (FCR):** the ratio of feed inputs to farmed fish output, most simply calculated as the dry weight of feed used, divided by the wet weight of fish harvested.

WI:FO	=	**Yield rate**	X	**Inclusion rate (%)**	x	**FCR**

The WI:FO is calculated for fishmeal and fish oil and the higher of the two values is used as the basis for the ranking for this criterion.

Yield rate

Yield rates vary depending on the species of fish, season, condition of fish, and efficiency of the reduction plants. Seafood Watch uses a wet fish to fishmeal conversion rate of 22% as suggested by Tyedmers (2000) as a reasonable year-round average conversion rate, and a fish oil conversion rate of 12%. These values mean that 4.5 units of wild fish from reduction fisheries are needed to produce one unit of fishmeal, and 8.3 units of wild fish are needed to produce one unit of fish oil. Until further literature is available, Seafood Watch® considers these to be the most accurate estimates for yield rates for fishmeal and fish oil in aquaculture since they represent year-round averages for Gulf of Mexico menhaden.

Inclusion rate

The inclusion rate is the percentage of fishmeal/oil included in the feed, and reflects the different dietary requirements for specific animals. Feed formulation also varies by life stage and manufacturer specifications. Salmon feeds typically contain relatively high amounts of fishmeal and fish oil compared to other farmed aquatic species (Naylor *et al.* 2009). The global average of the inclusion rates for fishmeal and fish oil in compound feeds for salmon are estimated to be 24% and 16%, respectively (Tacon and Metian 2008). These figures cover the range for the entire life cycle of farmed salmon, including the hatchery phase. The EWOS Nature Diet used at Domsea Farms was used as a specific coho feed in this report. Information regarding formulation was verified by Mr. Jason Mann of EWOS feed company. Inclusion rates are 25% fishmeal and 10% fish oil, sourced primarily from wild menhaden, sardines, and anchovies (J. Mann 2009, pers comm.), although information regarding the specific fisheries is proprietary (Tacon and Metian 2008). Mr. Mann also verified that the fishmeal and oil in this feed is sourced from herring and hake processing byproducts in the following amounts: 4.8% of the fishmeal and 2.7% of the fish oil (J. Mann 2009, pers comm.). Based on the Seafood Watch criteria, these are subtracted from the inclusion rates for the purpose of the WI:FO calculations. Thus, 20.2% of the fishmeal and 7.3% of the fish oil included in the feed comes directly from forage fisheries. These inclusion rates, particularly for oil, are significantly lower than typical salmon feed formulations.

Feed Conversion Ratio (FCR)

The feed conversion rate (FCR) is generally defined as the ratio of total feed weight used to the net production output (total weight gained by the stock) over one or more farming cycles (Weber 2003). This calculation is expressed as:

$$\textbf{FCR} = \frac{\text{Feed Weight}}{\text{(Final Stock Wet Weight – Starting Wet Weight)}}$$

Estimates of FCR vary among aquaculture operations due to variability in the size of stock, farming conditions (Jory *et al.* 2001, Naylor *et al.* 2009), stocking densities, harvest size and prevalence of escapes. Globally, compound salmon feeds were estimated to have an FCR of 1.3 in 2007 (Tacon and Metian 2008). The value of FCR for fresh water coho salmon was reported to be 1.2 according to the feed company (J. Mann 2009, pers comm.), but due to uncertainty about whether this value accurately reflects the economic FCR at the farm level as well as potential variation, a global value of 1.3 is used in the WI:FO calculations to be precautionary. Since Seafood Watch used the global average, these values are consistent with other freshwater coho aquaculture tank based operations.

Wild Input to Farmed Output ratio (WI:FO)

Using the data above yields the following WI:FO calculations.

Product	Yield rate		Inclusion rate (%)		FCR		Wild Input: Fish Output
Meal	4.5	x	0.202	x	1.3	=	1.2: 1
Oil	8.3	x	0.073	x	1.3	=	0.8: 1

Although fish oil has a considerably lower yield level from wild fish than fishmeal, the low inclusion levels in these salmon feeds mean that fishmeal has a higher WI:FO value. The fishmeal value therefore dictates the amount of wild fish needed to produce a given amount of farmed coho salmon, in this case 1.2 kg of wild fish per kilogram of farmed coho salmon, which falls within the range considered ‘Moderate’ by Seafood Watch. Since this score is at the lower end of the ‘Moderate’ scoring range (1.1 – 2.0), the ‘Moderate’ score is considered to be quite robust to variation in fishmeal and oil inclusion rates or the FCR at different freshwater coho farms.

Secondary factor – Stock status of the reduction fishery

Although numerous management measures exist for the majority of the species used to produce fishmeal and fish oil (Barlow 2002), some fish stocks harvested to produce fishmeal and fish oil are considered fully exploited (Hardy and Tacon 2002). Forage fisheries are managed with total catch limits, area catch limits, minimum mesh sizes, fleet cap controls, closed areas, seasonal bans, and minimum landing sizes (Barlow 2002). For example—based on the species used in Domsea feed formulations—it is generally believed that U.S. stocks of Atlantic menhaden are not overfished (NMFS 2003), even though Atlantic menhaden is not managed by a federal Fishery Management Plan (FMP). The fishery is managed by the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Fisheries Management Plan for Atlantic Menhaden (AMPRT 2003). Peruvian anchoveta (anchovy) is usually a primary source of fishmeal feeds, and the fishery is generally not considered overfished as anchovy biomass has been increasing since the 1997/98 El Niño event (FIN 2004). Stocks are managed by licensing, seasonal closures, and a minimum landing size (FIN 2004). Pacific sardines are not overfished and are currently considered a Seafood Watch ‘Best Choice’ (Green). The fishmeal reduced in the type of EWOS feed used at Domsea Farms is derived from a mixture of anchovy, sardine, and menhaden at any given time (J.Mann 2009, pers comm.). Since the specific fisheries for these species have not been identified and their status cannot be accurately determined, this factor is given a ‘Moderate’ ranking. This ‘Moderate’ ranking is also valid for other freshwater coho farms that are unable to specify the precise source of the fishmeal and oil used in their feeds.

Secondary factor – Source of stock

Hatchery production (as opposed to wild collection) of eggs, fry and smolts is standard amongst all sectors of salmon farming, and freshwater coho is no exception. Domsea Farms sources Domsea pedigree coho strains from the AquaSeed hatchery, a practice that does not deplete wild populations and is thus a ‘Low’ conservation concern.

Synthesis

The WI:FO value is the dominant factor for Criterion 1, and is ranked a ‘Moderate’ concern with a value of 1.2:1. Thus, this industry does not contribute to an overall net protein gain. Marine resource use could be improved to a green ranking by further reductions in the use of marine resources in feed or production-specific FCR data. Since the feed is standard for coho, and the FCR used in these calculations is based on the global average (rather than at the farm-level), the WI:FO calculation is considered to be consistent with other freshwater coho tank-based aquaculture operations. With a WI:FO of 1:2:1 and the unknown status of the fisheries supplying these marine feed ingredients, the overall ranking for this criterion is ‘Moderate’.

Use of marine resources rank

Low	**Moderate**	High

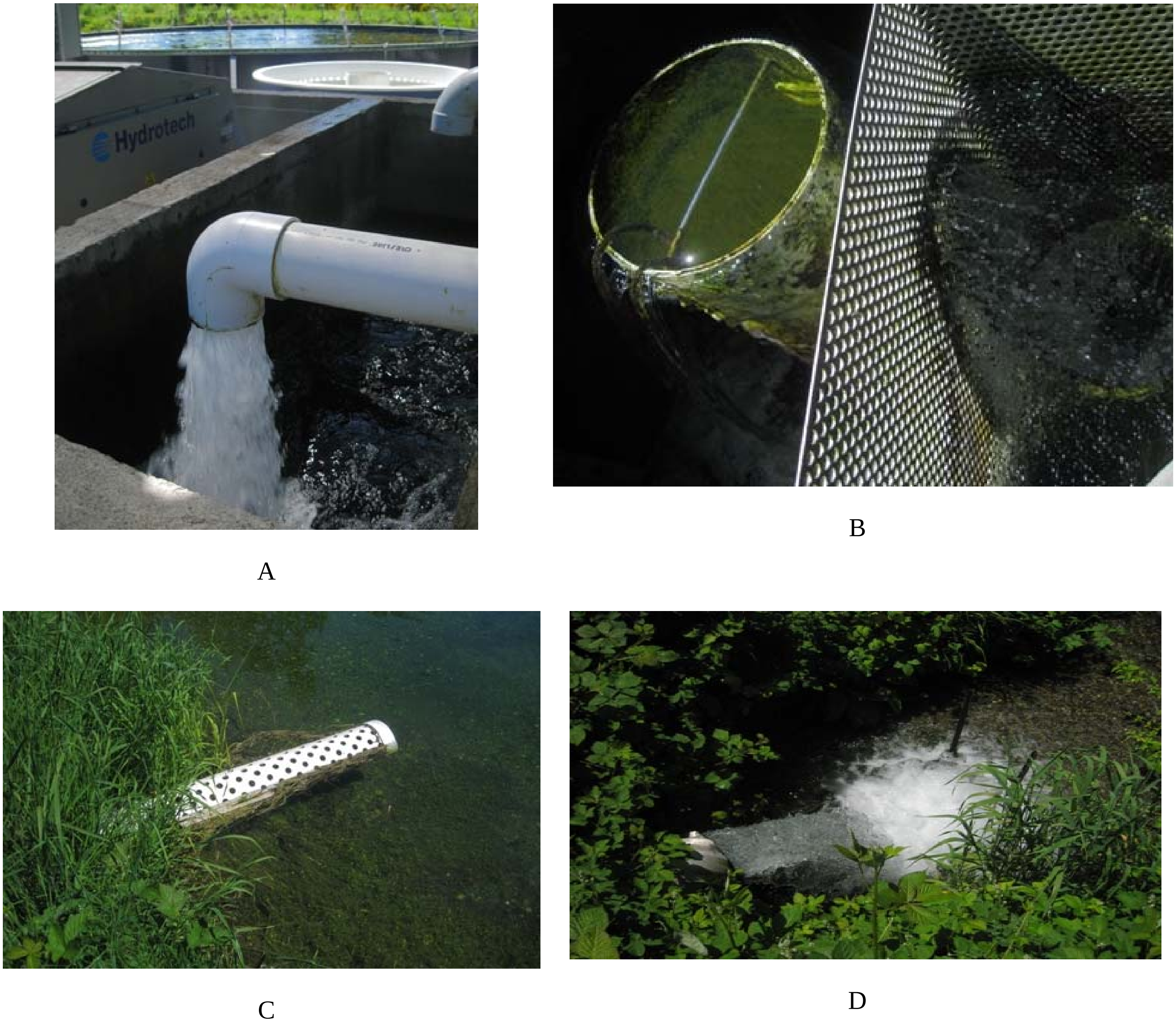

Figure 5. Water flow at AquaSeed’s Domsea Farms. (A) Pipe for influent second-use water entering the grow-out tanks; (B) grates providing physical barrier between grow-out tanks; (C) pipe between settling basins; (D) effluent flowing off farm to wetland (Photos by G. Shester, Monterey Bay Aquarium).

Criterion 2: Risk of Escaped Coho Salmon to Wild Stocks

Guiding principle: *Sustainable aquaculture operations pose no substantial risk of deleterious effects to wild fish stocks through the escape of farmed fish.*

Generally speaking, aquaculture has become one of the leading causes of exotic species introduction and concerns have been raised about the ecological impacts of escaped farmed organisms into the wild (Molnar *et al.* 2008). The potential negative impacts of escaped farmed organisms can be summarized into six concerns: genetic impacts, disease impacts, competition, predation, habitat alteration, and colonization (Myrick 2002). Escaped farmed organisms can negatively impact the environment and wild populations whether they are native to the area in which they are farmed or not. When escaped farmed fish are native to the region, interbreeding with wild populations can alter the genetic structure of the wild population and decrease overall population fitness. Escaped salmon can also compete with wild fish stocks for resources such as food, space, shelter, mates and redd (nest) building sites. The probability of significant ecological impact increases as the ratio of escaped fish to wild fish increases (Myrick 2002, Naylor *et al.* 2005, Hindar *et al.* 2006)

Aquaculture systems that are 'open' and thus have greater contact with the environment carry the greatest risk in terms of escapes; closed systems carry the lowest risk. In land-based flow-through and recirculation systems, the risk can be reduced by the effective use of physical barriers to reduce the escape of fish throughout their lifecycle (CAAR 2008). The risk is not limited to adult fish, as juveniles escaping from hatcheries may also pose ecological and genetic threats to the conservation of wild populations (Fleming and Gross 1993).

Primary factors

Effluent leaving the farm connects flow-through and partially recirculating systems directly to the external environment and fish escape typically occurs via effluent. Tank-based operations are able to control and prevent escapes by installing appropriate physical barriers such as grates and mesh screens. Escape prevention is contingent on the integrity of these structural barriers against small fish, eggs and larvae. Despite the impossibility of guaranteeing zero losses, escapes via effluent can be nearly eliminated by the presence of appropriately sized barriers.

Discharge characteristics will vary between farms, but as an example, Domsea Farms wastewater is discharged into settling ponds before leaving the farm and is dispersed through a wetland before eventually reaching potential contact with wild populations in the Black River. Escapes are minimized by the strategic placement of structural mechanisms (grates and mesh screens ranging from 1/16" to 3/8" on rearing tanks and 1.5" on the effluent discharge pipe) at multiple locations between the grow-out tanks and the final outflow. The placement of these barriers was verified during the visit by Seafood Watch staff (Fig. 5). Domsea Farms reports no instances of escape from the hatchery or farm during its existence (since 1993), and this has been independently verified by Mr. John Kerwin, Unit Leader of the Fish Program for the Washington Department of Fish and Wildlife (WDFW) Conservation Biology Unit. According to John

Kerwin, "*AIS [Aquatic Invasive Species] staff has routinely monitored streams and rivers downstream of numerous commercial hatchery operations throughout Washington State for the specific purpose of looking for escaped fish. They have reported to me that they never observed escaped fish from an AquaSeed owned or operated hatchery facility.*" (pers. comm., 2009)

Based on this evidence, the measures in place at Domsea Farms are deemed sufficient to limit escapes of fish, eggs and larvae from the facility. Although Domsea Farms demonstrates the ability of a freshwater coho farm to effectively prevent escapes, this does not mean that escapes will never happen. There is also the possibility, however slim, that catastrophic failure could result in the escape of significant numbers of fish. However, due to the simplicity of effectively screening water outlets at multiple locations, escapes are considered to be rare in freshwater coho salmon production. Thus, a 'Low' risk is accorded for 'evidence that farmed fish regularly escape to the surrounding environment.'

The physical location of an aquaculture operation influences the risk it poses to wild fish populations. Coho salmon are native to the U.S. and could potentially be impacted by interaction with escaped farmed coho. For example, at Domsea Farms, both wild coho and the Domsea strain are native to regional waterways since the cultivated strain originates from the Skykomish stock in Washington state (Neely *et al.* 2008). While it maintains interspecies characteristics, the cultivated strain is genetically distinct from wild stocks due to many generations of selective breeding. If fish escaped from Domsea Farms, the risk of interaction with wild fish in the Black River and other tributaries of the Chehalis River has not been established. The degree and consequences of such interaction would depend on the numbers of escaped fish, their life stage and other factors. It has been documented that coho of Skykomish origin perform poorly when released outside of their natal basin (Seidel 1977). Since Domsea Farms coho are native and their survival is believed to be low, the 'status of escaping fish' is determined to be a 'Low' conservation concern.

Secondary factors

Where wild coho are native to regional waterways, it is acknowledged that escapes are associated with the possibility of crossbreeding or disturbing the spawning of local wild coho populations. This could be problematic, leading to genetic introgression, however, tank-based freshwater production systems are able to secure and contain fish effectively. Without a high risk of escape events, the secondary factors 'genetic introgression through successful crossbreeding', 'spawning disruption of wild salmon' and 'competition with wild fish for limiting resources or habitats' are all 'Low' conservation concerns for U.S. freshwater coho salmon farming.

The proximity of freshwater coho farms to populations of threatened wild stocks is a critical factor in evaluating the risk posed by escaping fish. In the case of Domsea farms, wild stocks of Chinook salmon in the region are 'threatened' under state, federal and international law (NWR), although WDFW verified that there are no Endangered Species Act (ESA) listed fish in the Black River or the Chehalis River system watershed (J. Kerwin 2009, pers comm.). While it appears that endangered, threatened or protected wild stocks are not affected by the industry at this time, there is not enough evidence to prove the risk is low. Considering relative proximity to threatened populations, as a precautionary measure, this criterion ranks as a 'Moderate' risk to wild stocks.

Synthesis

Due to the closed nature of tank-based freshwater coho salmon production and the robust physical barriers that effectively prevent escapes, the risk posed to wild stocks is low. The potential to impact endangered, threatened or protected wild stocks, should escapes occur, is probably low but data are insufficient to prove this, and therefore this secondary factor is determined to be a 'Moderate' risk. Overall, the risk of negative environmental impacts from escaping farmed coho salmon is ranked a 'Low' conservation concern.

Risk of escaped fish to wild stocks rank

Low	Moderate	High	Critical

Criterion 3: Risk of Disease and Parasite Transfer to the Wild Stocks

Guiding principle: *Sustainable aquaculture operations pose little risk of deleterious effects to wild fish stocks through the amplification, retransmission or introduction of disease or parasites.*

Disease has caused major economic loss in all forms of agriculture and aquaculture. Salmon farming is no exception and has been plagued by various bacterial, viral, fungal and parasitic pathogens (see Seafood Watch Farmed Salmon Report). While economic losses are easily demonstrated, the impacts on wild stocks are more difficult to assess. ‘Pathogen pollution’, or the introduction of new disease-causing agents, is unequivocally increasing disease in the ocean and elsewhere (Lafferty *et al.* 2004). A similar type of pathogen pollution occurs where the concentration of domestic animals becomes an abundant source of hosts for disease. Such disease reservoirs can cause rare species to decline (Lafferty and Gerber 2002). Contact with a closely related native species is not always a prerequisite for spreading disease; some pathogens can be introduced to wild populations from farms through other aquatic organisms which act as carriers, or transported in effluent until reaching a new host.

Diseases afflicting coho salmon in general include furunculosis, Infectious Salmon Anemia (ISA), Enteric Redmouth Disease (ERM), Bacterial Kidney Disease (BKD), Kudoa, Vibriosis, Rickettsia and parasites such as *Caligus spp*. Existing treatments for these diseases, when available, include antibiotics and antiparasitic chemical treatments, and/or vaccination (Fairgrieve 2006). Other infections, damage to the GI tract or kidneys, starvation, undernourishment, and temperature shock are all known to contribute to stress (Hirvela-Koski *et al.* 2006).

Pacific salmon are very susceptible to BKD (Starliper *et al.* 1997, Jonas *et al.* 2002, Hay 2003, Nuhfer *et al.* 2005) making it the major disease afflicting tank-based fresh water salmon farms. It is the result of an infection with the bacterium *Renibacterium salmoninarum* which can be vertically transmitted via infected eggs and horizontally transmitted in both fresh and seawater via cohabitation with infected fish, ingestion, skin wounds, or contact with contaminated water (Noga 2000, Rhodes *et al.* 2006). The bacterium does not survive well outside a host, but likely has long-lasting viability in the kidneys or GI tracts of fish hosts, and is believed to be capable of lying dormant in a host fish before lysing or reactivating itself (Kipp 2007). Intensive inbreeding of coho salmon (Gallardo and Neira 2005) and stress are known to exacerbate disease, especially BKD in fish, since they contribute to immune system alteration and allow *R. salmoninarum* to flourish in host kidneys.

Treatments exist for BKD, but they are not fully effective and the disease tends to be persistent. The presence of this disease in aquaculture may threaten wild populations of fish if contact allows the pathogen to transfer. Other aquatic species have been shown to harbor *R. salmoninarum*—it has been isolated in sea lampreys in the Lake Ontario watershed (Eissa *et al.* 2006), Pacific hake in coastal British Columbia (Kent *et al.* 1998) and Pacific herring in B.C. fish hatcheries (Paclibare *et al.* 1988). How species act as reservoirs or contribute to the spread or extent of the disease is not known. Studies that have sampled wild salmon for the presence of

BKD in the Northeast Pacific have concluded that the pathogen may 'play a significant role in limiting salmon populations' (Sandell *et al.*), whereas studies examining bull trout infected with BKD in the wild have found that trout with BKD do not pose a high risk to the successful restoration of threatened populations with which they interact (2007). Nevertheless, the lack of available, efficacious antibiotics and vaccines for the treatment of BKD makes the disease notoriously 'very problematic' for the industry (Strom *et al.* 2005). The persistence of BKD and the continued failure to completely control it is a major threat to stakeholders, as evidenced by the many resources dedicated to the topic.

The fungal infection Saprolegniasis, caused by *Saprolegnia spp.* is a disease of concern in all types of salmon farming as well as in the culture of many other species in recirculating and flow-through aquaculture systems. It is ubiquitous in freshwater ecosystems and the main cause of fungal infections in freshwater fish and eggs (Whisler 1996, Mayer 2005, Phillips *et al.* 2008). Infection initiates as white or gray patches that resemble mold on epidermal tissues around the head or fins and pervades over the entire body. It is an opportunist facultative parasite, thus infection can be primary but is generally secondary to stress (Whisler 1996). *Saprolegnia* infected fish are indicative of weakened immune systems (Bruno and Wood 1994, Phillips *et al.* 2008). Spores may be transmitted by hatchery fish, wild fish, eggs, water supplies, or equipment and have been shown to be capable of infecting a wide variety of fish species (Bruno and Wood 1994, Whisler 1996). Since the fungus is almost always present in freshwater, it is assumed that some change in the fish occurs that allows a *Saprolegnia* infection to take hold (Bruno and Wood 1994). Therefore, amplification of spores by farms is not considered a direct threat to wild stocks.

Some amplification of diseases such as Saprolegniasis is inevitable when farming fish in tanks at high densities. Tank systems can provide a favorable environment for opportunistic pathogens when they are not flushed thoroughly and tanks are not cleaned routinely. Once a pathogen is established in a recirculation system, it can be difficult to eradicate and the system can act as incubator for the disease (CAAR 2008). Proper husbandry can greatly reduce the risks and levels of amplification. The use of Best Management Practices (BMPs) that lay the foundation for disease control is integral to all aquaculture operations. This includes effective biosecurity protocols to eliminate the opportunity for disease introduction; monitoring and surveying; diligent record keeping; and development of response plans in the case of disease outbreaks (including swift and effective eradication and/or quarantine when needed). A management practice that helps control pathogens and their associated diseases includes maintaining appropriate stocking densities to help minimize stress levels and thus opportunity for the disease to thrive (Fairgrieve 2006). Since vertical transmission is a large threat (Noga 2000), extra precautions to prevent contamination and spread of pathogens and their associated diseases at the hatchery level is also crucial. This includes routine screening for the pathogens in broodstock females at the hatchery level and careful elimination of cross-contamination from supplies used to treat infected fish or used at other farms.

Primary factors

The risks of disease introduction, amplification and retransmission to wild populations depend on various factors such as farm location, water sources and management, the nature of the production system, and the biosecurity protocols in place. Introduction of disease onto a farm greatly influences the risk of amplification. Risk of pathogen contamination is low at Domsea Farms because the freshwater entering the farm is sourced from groundwater with a very low probability of contact with wild fish disease vectors. Cross-contamination from shared equipment or supplies is also a very low risk because there are no other farms close by. While these conditions hindering introduction and amplification of disease are farm specific, other influential characteristics of this farm are not. The structure of the farm, in closed tanks, impedes contact with biota from outside the tanks, further decreasing the risk of introduction of disease onto the farm. Management practices used to control disease include continual monitoring and sampling of fish throughout their life stages, including in the hatchery.

Bacterial Kidney Disease is the most significant disease in this type of aquaculture system, and it cannot survive for long periods of time in the water column outside a fish host (Jones *et al.* 2007, Kipp 2007). Therefore, the risk of disease transfer primarily occurs if diseased fish escape and interact with wild fish. Risk of escapes is very low at Domsea Farms due to the presence of appropriate infrastructure that minimizes escapes (see Fig. 5 and *Criterion 2*). For the entire lifecycle, including the hatchery phase, fish do not come into contact with the surrounding environment, and thus the risk of spreading BKD to other fish is low. This was verified by Mr. John Kerwin of the Washington Department of Fish and Wildlife (WDFW), which samples for fish escapes and fish pathogens from commercial aquaculture (see *Criterion 2: Risk of Escapes* for the detailed statement)(J. Kerwin 2009, pers comm.). Therefore, there is a low risk of retransmitting disease to wild stocks via escaping fish.

It is recognized that even with low escape rates, waterborne pathogens that can pass through the structural barriers and survive through the settling ponds and wetland could still be a concern. Taking precautions to mitigate amplification of disease vectors within the grow-out tanks and subsequent proper treatment of effluent prevents the spread of disease vectors that could travel independently in the farm effluent. Although conditions are unique to this farm, Domsea Farms provides the example that if fungal spores were theoretically amplified inside grow-out tanks and exited the farm in effluent, they would be unlikely to reach wild fish populations in harmful amounts. This is due to effective settling or dispersion of the waterborne vectors traveling in the effluent, as it is channeled through settling ponds and a wetland before reaching the Black River. Thus, the risk of retransmitting disease to wild stocks via waterborne vectors is also low.

Adherence to an effective biosecurity protocol limits the risk of species introductions or translocations of disease and parasites to wild stocks. This was verified by Mr. John Kerwin in a statement reporting that AquaSeed facilities have been examined by staff from the Fish Health Unit, which monitors for disease in order to limit the introduction of viral and parasitic pathogens, and all reports have been negative for regulated fish pathogens at Domsea Farms and AquaSeed Corporation (J. Kerwin 2009, pers comm.).

The risk of introduction of disease vectors to the farm is low due to a pathogen-free water source and no chance of cross contamination with other farms. The risk of amplification of disease within the farm is low due to low rates of introduction of disease and prudent management including monitoring for disease. The risk of retransmission of disease to wild stocks is low because the risk of pathogen transfer via escapes from tank-based farms is low, and the risk of pathogen transfer via waterborne vectors is also low.

Thus, for U.S. freshwater coho farmed in tank-based systems, the risks posed to wild stocks for the primary factors 'Risk of amplification and retransmission of disease or parasites to wild stocks' and 'Risk of species introductions or translocations of novel diseases/parasites to wild stocks' are considered 'Low'.

Secondary factors

Moderate biosafety risks are inherent in any operation that discharges effluent. In tank-based farms that recirculate a large portion of their water, an introduced disease can amplify and potentially spread via effluent leaving the grow-out tanks. Thus, it is critical for a farm (or hatchery) to maintain an extensive biosecurity protocol to prevent introduction and amplification of pathogens that cause disease on the farm.

Domsea Farms and the AquaSeed hatchery maintain a comprehensive biosecurity protocol that includes the necessary components to prevent pathogens from entering the facility, moving and amplifying within the tanks, and moving out of the facility (APHIS 2008). One example is extensive tracking of pathogen transfer shown in transport records provided by Mr. Greg Hudson, General Manager and Ms. Camilla Timm, Sales Manager at AquaSeed Corporation, which showed that the farm complies with permits for the import, export, transfer and stock of live fish, viable eggs and gametes (C. Timm 2009, pers comm.). The farm maintains ongoing monitoring/screening programs for BKD with in-house staff and a certified consulting fish health pathologist. A federally accredited USDA veterinarian also monitors for disease every six months, and the samples are sent to a USDA certified fish health lab for analysis (G. Hudson 2009, pers comm.). As previously discussed, Mr. John Kerwin of the WDFW verified that "all of the fish health examinations from the AquaSeed facilities have been negative for regulated fish pathogens" (J. Kerwin 2009, pers comm.). The farm reports that it currently uses no chemicals, drugs, vaccines or antibiotics (P.Heggelund 2009, pers comm.), but this has not been confirmed by Seafood Watch.

Considering the use of pathogen-free groundwater sources, Domsea Farms considers vertical transmission to be the greatest threat of BKD transmission, and the AquaSeed hatchery purports to be diligent about removing females that have been detected to carry the causative agent of the disease (P. Heggelund 2009, pers comm.). In order to thwart the risk of horizontal transmission, moribund and dead fish are removed with daily flushing of the tanks, accumulated in a specific bucket and set aside for a local composting company to remove (P. Heggelund 2009, pers comm.). In addition, the Washington Department of the Ecology National Pollutant Discharge Elimination System (NPDES) permit with which the farm and hatchery comply requires disease control to be conducted in conformance with protocols (EPA 2004). Thus, the amplification of pathogens and their diseases does not appear to be a significant concern. Data are insufficient to deem this a low risk, however. As a flow-through operation, waste that is generated and continuously discharged via effluent into the surrounding environment has the potential to transfer pathogens to the surrounding environment. The criterion ‘bio-safety risks inherent in operations’ is therefore accorded a ‘Moderate’ conservation concern.

The risk of spreading disease or parasites to wild stocks is influenced by the proximity of freshwater coho farms to populations of threatened wild stocks. In the case of Domsea Farms, wild stocks of steelhead, coho and Chinook salmon in the region are “threatened” under state, federal or international law (NWR 2009), although WDFW verified that there are no Endangered Species Act (ESA) listed fish in the Black River or the Chehalis River system watershed (J. Kerwin 2009, pers. comm.). While it appears that the likelihood of the industry affecting endangered, threatened or protected wild stocks is low at this time, supporting evidence is insufficient. Considering the relative proximity to threatened populations, as a precautionary measure, this criterion ranks as a ‘Moderate’ risk to wild stocks.

SynthesisIntroduction of pathogens can be avoided through careful management, although it is likely that pathogen amplification will occur in farming operations if introduced. Factors that lower the risk of amplification therefore encompass practices that lower the risk of disease introduction along with prudent management practices to control disease when outbreaks occur. Risk of retransmission or spread of disease to wild stocks from farmed fish decreases by limiting contact with wild populations and decreasing the risk of disease vectors spreading to wild stocks. This includes preventing escapes and properly treating effluent. Some factors that lower the risk of disease introduction, amplification and retransmission are exclusive to Domsea Farms (a pathogen-free water source, no chance for cross-contamination with nearby farms) because of siting, while others are characteristic of all tank-based operations. Aquaculture in tanks carries a low risk of escapes and allows the opportunity to treat effluents, so the risk of spreading disease vectors from farmed fish to wild stocks is low. It is likely that the potential to impact endangered, threatened or protected wild stocks is low, but data are insufficient to definitively conclude that such is the case, and it is therefore determined to be a ‘Moderate’ risk. Overall, the risk of introduction and spread of disease and parasites to wild fish is a ‘Low’ conservation concern.

Risk of disease and parasite transfer to wild stocks rank

Low	Moderate	High	Critical

Criterion 4: Risk of Pollution and Habitat Effects

Guiding principle: *Sustainable aquaculture operations employ methods to treat and reduce the discharge of organic effluent and other potential contaminants so that the resulting discharge and other habitat impacts do not adversely affect the integrity and function of the surrounding ecosystem.*

It is generally believed that good water quality is paramount to optimum health and production in aquaculture (Subasinghe 2005). Like all animal production, aquaculture creates biological waste that must be treated and disposed of responsibly. If untreated and released directly into nearby water bodies, the effluent can negatively impact biota in a variety of direct and indirect ways (Gowen *et al.* 1990, Beveridge 1996, Costa-Pierce 1996). Effluent from aquaculture operations must meet water quality standards mandated by the Environmental Protection Agency (EPA) to comply with the U.S. Clean Water Act. The EPA's list of pollutants of concern from aquaculture facilities includes sediments, solids, nutrients, organic compounds and metals (EPA 2009). Aquaculture effluent is typically rich in nitrogen and phosphorous, with the latter being of particular interest as it is a key limiting nutrient in freshwater ecosystems and enters the farm primarily via fishmeal in feeds (particularly if fish processing by-products are used in the feeds).

Tank-based aquaculture, even if operated on a flow-through basis, offers the potential to treat effluent water to remove particulate and soluble wastes before discharge from the farm. Recirculating aquaculture systems are reputed to be free of negative pollution consequences (Piedrahita 2003) because they do not discharge effluent. In practice, this is not the case. Fish wastes, particularly particulate wastes from mechanical filtration, settling ponds, or biofilter sludge, need to be collected in some way and disposed of.

Unlike open systems such as net pens, recirculating systems offer the potential to collect wastes and dispose of them in a controlled manner. The ability to control the effluent also allows the producer to employ Industrial Ecology (IE) concepts to deal with the by-products in an efficient and economical way. One example of this is the use of dredged solid waste from settling ponds as a fertilizing aid in the production of other food crops. A study using effluent from a recirculating freshwater salmon aquaculture farm in British Columbia as a water and nutrient source found that wasabi and hybrid poplar plants effectively remove a portion of soluble nitrate and phosphorus via uptake during regular growth (Ehret and Swift 2005). The farm (Swift Aquaculture in B.C.) now cultures crayfish and wasabi plants with the effluent from their salmon grow-out tanks after passing it through a filter to remove solids (CAAR 2008).

Part A: Effluent effects

In order to evaluate the local and regional ecosystem effects of effluent, it is important to consider the extent of treatment, evidence of substantial local and regional effects and compliance with standards. Although freshwater coho farms are 'closed' operations in terms of structure and recirculate a large portion of water, they discharge effluent that must be treated. For example, Domsea Farms treats effluent by directing discharge through a series of settling ponds

(Figures 3, 5). In theory, suspended solids should collect on the bottom as a sediment layer that can be removed and disposed of or re-used in another capacity. Domsea Farms stocks rainbow trout (*Oncorhynchus mykiss*) in these ponds, which may interfere with the settling process. According to Per Heggelund, the owner of Domsea Farms and AquaSeed Corporation, the settling ponds are dredged approximately every two years or as needed (P. Heggelund 2009, pers comm.) for use as an agricultural fertilizer. Due to the fact that the Domsea Farms effluent is settled in basins designed for this purpose, the risk posed by effluent water is ‘Low’.

No explicit evidence was available to support the presence or absence of substantial local or regional effluent effects due to effluent from Domsea Farms. Seafood Watch staff verified that effluent from Domsea Farms flows into the Black River (Fig. 5). The density of suspended solids relative to outflow rate is known to be low, as reflected in information provided by Mr. Robert Lewis of Dragon Labs, an environmental laboratory accredited by the Washington Department of Ecology (R. Lewis 2009, pers comm.). This lab analyzes outfall samples on a bi-monthly basis as mandated in the NPDES permit to meet EPA Clean Water Act requirements. A statement provided by Mr. Aziz Mahar, an environmental engineer with the Washington Department of Ecology showed that effluent has been within tolerable limits for six parameters and is in compliance with limits mandated in the NPDES permit (R. Lewis 2009, pers comm., A. Mahar 2009, pers comm.). While compliance with their National Pollutant Discharge Elimination System (NPDES) permit shows that the farm is law abiding, it does not preclude contributions to substantial local or regional effluent effects. As long as a farm discharges effluent, the potential risk for negative effects on the environment exists. Although the industry is compliant with applicable regulations, information regarding local and regional effluent effects is largely unavailable, thus the risks for ‘local and regional effluent effects’ are ranked ‘Moderate’.

Table 1. Example of effluent limits for Domsea freshwater coho farm (EPA 2004).

Parameter	Maximum Daily Discharge Allowed
Biochemical Oxygen Demand	210 pounds
Ammonia	84 pounds
Total Phosphorus	16 pounds

The Clean Water Act requires compliance with a number of parameters to meet the surface water quality effluent limits that act as a gauge to measure efficacy of this form of effluent treatment (see Effluent Discharge in *Criterion 5* for further information). Monitoring data provided by Dragon Labs shows that the suspended solids in the farm’s effluent has been well below regulatory limits for Biochemical Oxygen Demand, Total Suspended Solids, Hardness, Nitrogen Ammonia, Total Phosphorus and pH since June 2006 (R. Lewis 2009, pers comm.). Limits set for Domsea Farm for several of these parameters are shown in Table 1. Quality of ‘treatment’ is verified to be sufficient from frequent effluent testing (R. Lewis 2009, pers comm., A. Mahar 2009, pers comm.). While the effluent standards set for this farm cannot be verified to be effective in preventing negative ecosystem effects, the above documentation showing that Domsea Farms complies with set standards makes the 'extent of local or regional effects' a 'Low' risk.

Figure 6. Settling pond at AquaSeed (Photo by G. Shester, Monterey Bay Aquarium).

Part B: Habitat effects

Domsea Farms is located inland on previously agricultural land, adjacent to a riparian wetland. It is not considered to be an area of high ecological sensitivity. The site of production and the effluent outfalls are sufficiently distant from other aquaculture operations that might also be emitting waste effluent. Therefore, the risk of 'impacting habitats' is considered to be 'Low'.

The extent of operations also plays a role in effects on habitat. The density of sites relative to the flushing rate of the system is not high given the fact that this is the only commercial operation in the region. At Domsea Farms, the effluent flows into the Black River after leaving the settling basins, but the density of suspended solids in the effluent is low relative to the outflow rate. The effluent is also known to meet set standards for the parameters sampled according to the NPDES permit (see Part A, above, and *Criterion 5: Effectiveness of Management Regime*). Therefore, there is a 'Low' risk with respect to potential to impact habitats due to the 'extent of operations'.

Synthesis

Overall, due to the nature of the production system and its isolation, the potential to negatively impact habitat via effluent effects, both locally and regionally, appears low. However, evidence is insufficient to prove or disprove any negative effects on the surrounding habitat to date. Effluent is settled in basins, and outfall sampling data show the farm effluent meets EPA Clean Water Act requirements. This farm is sited outside sensitive wetlands and is distant from other aquaculture operations that could contribute to cumulative effects on the environment. Increasing use of fully recirculating systems should further isolate the farm from any impacts on this habitat. Considering the regulatory requirements for farm siting and effluent monitoring, the risk of pollution and habitat damage from freshwater coho salmon farms is considered to a be 'Low' conservation concern.

Risk of pollution and habitat effects

Low Moderate High

Criterion 5: Effectiveness of the Management Regime

Guiding principle: The management regime of sustainable aquaculture operations respects all local, national and international laws and utilizes a precautionary approach, which favors conservation of the environment, for daily operations and industry expansion.

The U.S. has a multi-jurisdictional framework for salmon aquaculture, regulated by a conglomeration of national government organizations (Laszczak *et al.* 2004, MATF 2007). Duties are delegated to various committees and agencies such as the Joint Subcommittee on Aquaculture (JSA), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Army Corps of Engineers, the United States Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) (Laszczak *et al.* 2004). As the U.S. federal oceans agency, NOAA promotes the best use of the country's ocean resources through its five branches that work to increase productivity and environmental awareness. One such branch, the Office of Oceanic and Atmospheric Research, is responsible for research projects and running the National Sea Grant College Program that funds ocean-related college research (see Table 2 for a complete list of government agencies that play a role in aquaculture in the U.S.).

The USDA has primary jurisdiction over aquaculture with five Regional Aquaculture Centers (RACs) (Laszczak *et al.* 2004) that regulates all biologics (Prater 2007). The USDA's Animal and Plant Health Inspection Service (APHIS) is the federal leader in fish health monitoring and disease elimination. It oversees surveillance of "OIE reportable" (i.e., tracked by the World Organization for Animal Health) Commercial Food Fish diseases (APHIS 2008). It has a National Aquaculture Program that is managed by the APHIS Veterinary Services (VS) and Wildlife Services. The VS certifies the health status of live fish and fish products for export, approves of laboratories to perform diagnoses, negotiates with foreign countries to guarantee appropriate and safe risk assessments, and regulates the production and sale of vaccines and biologic reagents used in fish (APHIS 2008, NAHRS 2009).

Table 2. Regulations governing aquaculture in the U.S. (Normandeau Associates Inc. and Battelle 2003).

Law	**Jurisdiction**	**Description**
Section 402, Federal Water Pollution Control Act (33 U.S.C. 402)	EPA, delegation to Washington Department of Ecology	NPDES permits
Section 403, Federal Water Pollution Control Act (33 U.S.C. 403)	EPA	Ocean Disposal Criteria
Section 103, Marine Protection Research and Sanctuaries Act (16 U.S.C. 1431)	USCOE	Disposal of dredged material in ocean waters

Section 404, Clean Water Act (33 U.S.C. 404)	USCOE	Fill in waters in the United States
Rivers and Harbors Act of 1899 (33 U.S.C. 403)	US ACOE	Governs structures in navigable waters
The Migratory Bird Treaty Act (16 U.S.C. 703 et seq.)	USFWS	Depredation permit required to kill protected species
Endangered Species Act (16 U.S.C. 1531 et seq.)	USFWS/NMFS	Protects federally listed species and their habitats
Marine Mammal Protection Act (16 U.S.C. 1361 et seq.)	NMFS	Protects marine mammals
Magnuson Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 et seq)	NOAA	Governs Essential Fish Habitat
Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. 136 et seq.)	EPA	Pesticide control
The Food, Drug, and Cosmetic Act (21 U.S.C. 301 et seq.)	FDA	Drug approval program

The Joint Subcommittee on Aquaculture (JSA) brings together representatives from federal agencies along with many others including the Secretaries of Agriculture, Commerce, and Energy. The Subcommittee's meetings include discussions of current overlapping issues in aquaculture and the creation of recommendations to address these issues (Laszczak *et al.* 2004).

The FDA has traditionally inspected fish, and hence compounds used in for treatment of fish (e.g., for sea lice) are regulated by the FDA (EPA 2009, USDA 2009). The EPA is charged with overseeing the distribution, labeling, sale and use of all pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). It monitors major regulation updates and procedures in 15-year cycles. The EPA also controls pollution from compounds used in feed for the diagnosis, treatment, cure, prevention, or mitigation of disease in fish.

In 2004, the EPA finalized guidelines pertaining to the discharge of wastewater from concentrated aquatic animal production operations. Facilities that produce at least 100,000 pounds a year in flow-through and recirculating systems that discharge wastewater at least 30 days a year must (EPA 2009):

- Prevent discharge of drugs and pesticides that have been spilled and minimize discharges of excess feed;
- Regularly maintain production and wastewater treatment systems;
- Keep records on numbers and weights of animals, amounts of feed, and frequency of cleaning, inspection, maintenance, and repair;

- Train staff to prevent and respond to spills and to properly operate and maintain production and wastewater treatment systems;
- Report the use of experimental animal drugs or drugs that are not used in accordance with label requirements;
- Report failure of or damage to containment systems; and
- Develop, maintain, and certify a Best Management Practice plan describing how the facility will meet these requirements.

The rules also require flow-through and recirculating discharge facilities to minimize the discharge of solids such as uneaten feed, settled solids and animal carcasses.

In order to enforce the Clean Water Act at the state level, National Pollutant Discharge Elimination System (NPDES) permits are granted to aquaculture facilities. The NPDES permitting process is meant to control water pollution by regulating point sources that discharge pollutants into federal waters (MATF 2007, EPA 2009). It sets allowable “tolerances” (pesticide residue levels) to regulate the amount of chemicals in effluent (Laszczak *et al.* 2004). Tolerance levels are set at the federal level, but individual states can set more stringent tolerance levels if desired (EPA 2009). Surface water quality-based effluent limitations may be based on individual waste load allocations (WLA) or on a WLA developed during a basin-wide Total Maximum Daily Load study (TMDL) (EPA 2004) that takes into account other farms or other discharges. For Domsea Farms, the permit was granted by the Washington Department of Ecology under the Sediments Environmental Review Section and the Water Quality Program.

In the case of Domsea Farms, the Black River has a TMDL study, although it was completed in 1994 (EPA 2004). The farm’s NPDES permit (last modified in 2003 and valid until 2010) specifies the effluent characteristics discussed in *Criterion 4 – Pollution and Habitat Effects.*

Primary factors

Application of existing laws

The U.S. aquaculture industry is regulated by federal, state and local laws. There are three main types of permits issued for aquaculture in the U.S.: those that regulate siting, those that regulate discharge, and those addressing biosecurity issues (exotics/disease). Siting permits do not require regular data collection or inspection, while discharge and biosecurity-related permits have metrics that require ongoing monitoring and reporting.

Domsea Farms demonstrates compliance with applicable regulations. The operation has been granted all necessary transport permits, which were provided to Seafood Watch. Domsea Farms complies with the standards of the federal Clean Water Act, enforced by the EPA through conditions stipulated in the NPDES permit (discussed above). Standards stipulated in Domsea Farms NPDES permit place limitations on surface water quality, and this farm demonstrated compliance with effluent standards for the parameters required in their NPDES permit. This was verified by the Department of Ecology as well as in a statement provided from Mr. Robert Lewis of Dragon Labs, which samples the effluent bi-monthly (R. Lewis 2009, pers comm.) Therefore, the farm is considered in compliance with existing federal, state and local laws and is ranked as a 'Low' risk for pollution and habitat effects.

Siting licenses

Licensing to control the siting, number and size of fish farms is governed by the Section 404 regulatory program of the Clean Water Act. Section 404 regulates the discharge of dredged or fill material into the nation's waters and establishes enforceable requirements. Permits can be issued to private parties and governmental agencies for construction in wetlands, streams, rivers and other aquatic habitats. The United States Army Corps of Engineers (ACE) administers Section 404 under the purview of the Environmental Protection Agency (EPA), and issues permits related to siting and 'Dredge and Fill' activities. In addition, the United States Fish and Wildlife Service is responsible for investigating the nature of potential fish and wildlife impacts during the Section 404 permitting process (Holmberg 1998). Domsea Farms is sited appropriately, inland on previously agricultural land adjacent to a riparian wetland that is not in an area of high ecological sensitivity. The site of production and effluent outfall are sufficiently distant from other aquaculture operations that might also be emitting waste via effluent. At present, evidence presented in Criterion 4: Risk of Pollution and Habitat Effects shows that while some risks are unknown, effluent effects due to siting appear to be low risk. Since the currently regulated siting is effective, the criterion "use of licensing to control the location, number, size and stocking density of farms" is determined to be a 'Low' risk.

Better management practices

For this criterion, Seafood Watch assesses the existence and effectiveness of 'Better Management Practices', especially in terms of reducing escapes. In addition to the variety of permits required by different government agencies, EPA guidelines state that concentrated aquatic animal producers (farms) must develop their own BMPs to describe how their facility will meet the set requirements. The United States Department of Agriculture Natural Resources Conservation Service (NRCS) has extensive BMPs that are publicly available online for inland aquaculture, e.g., the Conservation Practice Standard for 'Fish Raceway or Tank' (NRCS 2001).

Domsea Farms follows BMPs to prevent escapes, such as placement of structural mechanisms (grates, mesh screens ranging from 1/16" to 3/8" on rearing tanks and 1.5" on the effluent discharge pipe) at multiple locations between the grow-out tanks and the final outflow. This was verified during the visit by Seafood Watch staff (Fig. 5). These structures are known to be effective at reducing escapes of fish, eggs and larvae as verified by Mr. John Kerwin, the Unit Leader of the Fish Program for the Washington Department of Fish and Wildlife (WDFW) Conservation Biology Unit (see Criterion 2: Risk of Escaped Fish to Wild Stocks). The use of BMPs appears to be effective in freshwater coho salmon farming in the U.S., especially for preventing escapes, and therefore this criterion is ranked as a 'Low' risk.

Disease prevention

The U.S. is a member country of the Office International des Epizooties (OIE), also known as the World Animal Health Organization, which provides recommendations to control the introduction and proliferation of diseases through its Aquatic Animal Health Code (MATF 2007). As a member, the U.S. agrees to abide by international standards to reduce the risks of spreading disease through trade. An example of guidelines set by the OIE is the standardized sampling procedure for laboratory examinations (MATF 2007). The USDA's Animal and Plant Health Inspection Service (APHIS) is the federal leader in fish health monitoring and disease elimination. It oversees surveillance of "OIE reportable" Commercial Food Fish diseases (APHIS 2009, NAHRS 2009). It has a National Aquaculture Program that is managed by the APHIS Veterinary Services and Wildlife Services. The VS certifies the health status of live fish and fish products for export, approves of laboratories to perform diagnoses, negotiates with foreign countries to guarantee appropriate and safe risk assessments and regulates the production and sale of vaccines and biologic reagents used in fish production (APHIS 2008, NAHRS 2009).

The USDA is also responsible for the National Center for Animal Health Emergency Management, which controls the Emergency Management Response System, although emergency measures are often implemented via local authorities. Biosecurity measures including disease prevention are regulated by state agencies and require regular monitoring under additional requirements of the NPDES permit. Freshwater coho farms are therefore required to comply with the disease monitoring and reporting protocols discussed in *Criterion 3*. Any fish movement requires a Fish Transport permit from the state Department of Fish and Wildlife. Oversight at the state level is the duty of the state's Department of Fish and Wildlife. In the case of Domsea Farms, the Washington State Department of Fish and Wildlife (WDFW) manages aquaculture and controls pathogens and disease under state laws collectively known as the Revised Code of Washington (RCW) and the Washington Administrative Code (WAC). Clearly, there are many measures in place to control disease in aquaculture in the U.S.

In the future, the federal government plans to continue to manage and control pathogens and disease in aquaculture through the federal Draft National Aquatic Health Plan. The plan is currently in the process of internal agency review before JSA review and clearance by the Executive Branch's Office of Science and Technology Policy to be followed by stakeholder review and comment. The plan will emphasize protecting the health of cultured aquatic animals, and cover certification of farms, surveillance schemes, emergency planning, and control of disease (through eradication, identification and establishment of logical pathogen zones, and bio-security and transport control measures) (Laszczak *et al.* 2004, Scarfe *et al.* 2005, MATF 2007). Plan priorities include ensuring the availability of diagnostic, inspection, and certification services for disease, minimizing the impact of diseases that result from interactions between cultured and wild aquatic resources, and providing access to comprehensive species and pathogen and disease-specific information (Rolland *et al.* 2005, NAAHP 2007, APHIS 2008, AIN 2009, USDA 2009).

These measures, especially the use of Better Management Practices, are effective at preventing the introduction, amplification and spread of disease at Domsea Farms. The BMPs used to reduce the risk of introducing and amplifying disease on the farm and spreading disease to wild stocks are detailed in *Criterion 3: Risk of Disease and Parasite Transfer to Wild Stocks*. Domsea Farms has been successful in preventing disease introduction to their facility due to the use of a clean water source, ongoing monitoring at the hatchery, and adherence to transport permits. The farm has been successful at preventing amplification of any disease within their facility by practicing prudent husbandry and removing moribund fish. The spread of disease to wild stocks is controlled by preventing escapes and properly settling effluent before discharge. Information about escapes and disease was verified and detailed in *Criterion 2: Risk of Escapes* and *Criterion 3: Risk of Disease*. Therefore, current measures to prevent disease and treat outbreaks are effective and this criterion is ranked as a 'Low' risk.

Regulations for therapeutants and their release

The FDA and EPA share the duty of regulating pesticides, and the effectiveness of this division of regulation has been criticized in the past (Normandeau Associates Inc. and Battelle 2003). Regulations are sufficient for the freshwater coho salmon industry at this time, especially as Domsea Farms does not use any regulated chemicals in its operations.

The FDA has traditionally inspected fish and thus has regulatory jurisdiction over compounds used for the treatment of fish (EPA 2009). The EPA oversees the distribution, labeling, sale and use of all pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Major regulations and procedures for monitoring are updated in 15-year cycles. As the release of therapeutants used in the diagnosis, treatment, cure, prevention, or mitigation of disease in fish is considered part of pollution, the EPA also controls the use and discharge of these compounds. Allowable "tolerances" (pesticide residue levels) are set forth in NPDES permits to regulate the amounts of chemicals discharged in effluent (Laszczak *et al.* 2004). Tolerance levels are set at the federal level although individual states can set more stringent tolerance levels if desired (EPA 2009). A list of approved chemical treatments for use in U.S. aquaculture that has been established by the FDA and enforced via the Center for Veterinary Medicine (CVM) can be found on the FDA website (www.fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/Aquaculture/ucm132954.htm).

Investigational New Animal Drugs (INADs) approved by the FDA may be used under the additional restrictions of the state NPDES permit. Despite criticism that may be warranted for other sectors of aquaculture in the U.S., these regulations are considered sufficient in their application to the current freshwater coho farming industry, and thus this criterion is determined to be a 'Low' risk.

Predator control

While simple predator control devices such as nets and fences are common in freshwater aquaculture production, predators are not considered to be a specific problem in tank-based aquaculture and lethal control methods are unlikely to be necessary. Since predator deterrents are not used, the risk to the environment due to predator control from this farm is ‘Low.’

Expansion of the industry

At present, there is no comprehensive U.S. federal policy regulating aquaculture. Critics maintain that current regulation is ineffective because no one agency coordinates activities, resulting in a net loss of accountability and negative effects on the environment (MATF 2007). For example, the duty to regulate pesticides in aquaculture is shared by the FDA and the EPA, and is not considered highly effective (Normandeau Associates Inc. and Battelle 2003). However, Seafood Watch considers the various policies implemented by agencies at the federal, state and local levels that govern the freshwater coho salmon industry to be appropriate and effective at this time.

As the industry expands, adherence to the precautionary principle is not immediately apparent across all aquaculture policies for freshwater coho salmon farming in the U.S. It appears that some aspects of the industry will develop in a sustainable way while others are questionable. Use of Better Management Practices will allow farms to expand appropriately into the future. The development of the National Aquatic Animal Health Plan will allow for sustainable expansion in terms of disease monitoring and control.

It cannot be determined whether the use of licensing to control siting and the NPDES permitting process will prevent cumulative impacts to sensitive habitats as the industry expands into the future. According to the Marine Aquaculture Task Force report of 2007, the EPA’s regulation of effluent through NPDES permits at the state level is the major law regulating the environmental aspects of aquaculture. At present, this is effective because aquaculture facilities, especially the freshwater coho farms, are currently a relatively minor contribution to water pollution in the U.S. (MATF 2007). It is not clear that the establishment of Total Maximum Daily Load levels effectively considers cumulative effluent impacts on habitat as evidenced by lack of requirement for studies documenting the health of benthic communities, signature species and modified redox potential. The extent to which farm expansion and the construction of new farms would be regulated to minimize the negative effects of effluent discharge in the future is uncertain. The EPA’s current regulations, as enforced through NPDES permits, are not guaranteed to be environmentally protective. As the primary vehicle for federal regulation of some of the activities that occur in wetlands, one might assume that NPDES permits would be protective of habitats sensitive to effects of effluent, but it cannot be assumed that this is the case. A report by the Marine Aquaculture Task Force (2007), discusses the fact that NPDES permits do not necessarily preclude negative effluent effects. This is because the EPA’s effluent limitation guidelines for aquaculture discharges are weak, and enforcement via the use of discharge permits at the state level are inconsistent and variable in their level of rigor. Additionally, some states have general permits that cover most aquaculture facilities (e.g., ponds), and preclude the requirement for individual permits. Current oversight relies more heavily on process-based controls such as BMPs, instead of outcome-based controls such as quantitative effluent limits, which complicates measurement of the contribution of aquaculture to pollution (MATF 2007).

Overall, the U.S. regulatory structure is considered sufficiently robust and effective in dealing with the current small freshwater coho industry, which integrates many Better Management Practices into its operations. Considering future expansion however, it is not clear that the current pluralistic method of regulation over aquaculture in the U.S. will guide development in a sustainable way. Therefore this criterion is ranked as a 'Moderate' risk.

Synthesis

Federal and state regulations regarding effluent release, site development, biological security, and drug and chemical use are in place and enforced. Extensive better management practices have been adopted by Domsea Farms, which dominates the industry at this time. The farm effectively controls for disease, and chemical use is minimal. Permitting processes enforce transport of aquatic species and monitoring of farm effluent through an NPDES permit. The extent to which monitoring and regulation for disease and effluent release is effective and does not allow freshwater coho farms to exert negative environmental effects is unknown. It appears to be effective at this time due to the small scale of the industry and Domsea Farms prudent management practices with respect to biosecurity. There is federal recognition that environmental responsibility is an important issue to consider when expanding the U.S. aquaculture industry as a whole, but it is not clear that all of the current policies will guarantee sustainable expansion of the industry.

The regulations governing the U.S. freshwater coho salmon industry appropriately address issues of concern at this time. Therefore, a "Highly Effective" ranking is accorded to U.S. freshwater coho salmon farming for effectiveness of management.

Effectiveness of the management regime

Highly Effective Moderately Effective Ineffective

IV. Overall Evaluation and Seafood Recommendation

This report details farming of coho salmon in freshwater tanks in the U.S. based on the main U.S. operation, Domsea Farms. Tank-based operations allow for a high level of control due to the structural barrier between the farmed salmon and the natural environment that prevents many of the negative environmental consequences associated with marine net pen salmon farming. Freshwater coho has been given a ‘Moderate’ rank for marine resources use due to a ‘Wild Fish In to Farmed Fish Out’ ratio (WI:FO) of 1.2:1. The risk to wild stocks in terms of escapes and spread of disease are ‘Low’ due to the placement of multiple structural barriers that are effective at preventing escapes as well as conditions that lower risk of disease introduction to the farm and adherence to a biosecurity protocol that reduces amplification and spread of disease. Pollution and the risk of negative habitat effects are ‘Low’ since effluent is settled in basins and sampled to ensure compliance with permissible levels as stipulated in the facility’s NPDES permit. In addition, current operations are situated away from sensitive habitats. While it is unclear whether current policies would support sustainable development of the industry as it expands, the current management regime for this farming system is consistent and compliant with regulations that sufficiently oversee siting, discharge of waste and risk due to escape and disease. Therefore, this criterion is also of ‘Low’ conservation concern. Overall, U.S. freshwater coho salmon produced in freshwater tanks receives a ranking of ‘Best Choice’ (Green).

While current operations are deemed a ‘Best Choice’, Seafood Watch recognizes that inland freshwater coho salmon farming is a new industry. Some aspects of this ranking are based on the specific ecological context and voluntary practices of the particular operation observed for this assessment. To help guide expansion of existing operations and new operations, we provide the following recommendations to improve sustainability and maintain a ‘Best Choice’ ranking.

1. **Encouraging the use of (or conversion of existing farms to) completely closed, recirculating systems.** The risk of escapes, disease transmission, and effluent discharge can be further reduced by converting to a fully closed operation, which reduces the amount of effluent exiting the recirculating tanks.

2. **Reducing marine resource use in feed**. The proportion of fishmeal and fish oil used is currently relatively low for this form of salmon farming but still contributes to overall depletion of fisheries. Freshwater-farmed coho operations could play a leadership role for the industry if inclusion rates and feed conversion ratios are further decreased.

3. **Improved disease control.** While the risk of disease was not ranked high in this report, it is a critical part of sustainable aquaculture that should not be overlooked. Continued improvement to biosecurity plans, particularly addressing fungal infections, should be the focus of this effort. Conversion to fully recirculating systems will require additional pathogen treatment. Active use of the national aquatic animal health-monitoring program, when available, is recommended.

4. **Efficient energy consumption.** Although energy use was not assessed in this report, flow-through and recirculating aquaculture systems have been criticized for their high rates of energy use. Freshwater coho farms would benefit from the development of an alternative energy program in which they evaluate, track, and seek out ways to mitigate overall energy use and incorporate renewable energy technologies into their methods.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Use of Marine Resources		√		
Risk of Escaped Fish to Wild Stocks	√			
Risk of Disease and Parasite Transfer to Wild Stocks	√			
Risk of Pollution and Habitat Effects	√			
Management Effectiveness	√			

Overall Seafood Recommendation

Best Choice Good Alternative Avoid

Acknowledgments

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Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Aquaculture Evaluation

Species: Freshwater coho salmon	**Region:** U.S.

Seafood Watch™ defines sustainable seafood as from sources, whether fished or farmed, that can maintain or increase production into the long-term without jeopardizing the structure or function of affected ecosystems.

The following **guiding principles** illustrate the qualities that aquaculture operations must possess to be considered sustainable by the Seafood Watch program. Sustainable aquaculture:

- uses less wild caught fish (in the form of fish meal and fish oil) than it produces in the form of edible marine fish protein, and thus provides net protein gains for society;
- does not pose a substantial risk of deleterious effects on wild fish stocks through the escape of farmed fish[2];
- does not pose a substantial risk of deleterious effects on wild fish stocks through the amplification, retransmission or introduction of disease or parasites;
- employs methods to treat and reduce the discharge of organic waste and other potential contaminants so that the resulting discharge does not adversely affect the surrounding ecosystem; and
- implements and enforces all local, national and international laws and customs and utilizes a precautionary approach (which favors conservation of the environment in the face of irreversible environmental risks) for daily operations and industry expansion.

Seafood Watch has developed a set of five sustainability **criteria,** corresponding to these guiding principles, to evaluate aquaculture operations for the purpose of developing a seafood recommendation for consumers and businesses. These criteria are:

1. Use of marine resources
2. Risk of escapes to wild stocks
3. Risk of disease and parasite transfer to wild stocks
4. Risk of pollution and habitat effects
5. Effectiveness of the management regime

Each criterion includes:

- Primary factors to evaluate and rank
- Secondary factors to evaluate and rank
- Evaluation guidelines[3] to synthesize these factors
- A resulting **rank** for that criterion

Once a rank has been assigned to each criterion, an **overall seafood recommendation** for the type of aquaculture in question is developed based on additional evaluation guidelines. The ranks for each criterion, and the resulting overall seafood recommendation, are summarized in a table.

[2] "Fish" is used throughout this document to refer to finfish, shellfish and other farmed invertebrates.
[3] Evaluation Guidelines throughout this document reflect common combinations of primary and secondary factors that result in a given level of conservation concern. Not all possible combinations are shown – other combinations should be matched as closely as possible to the existing guidelines.

Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choices/Green: Consumers are strongly encouraged to purchase seafood in this category. The aquaculture source is sustainable as defined by Seafood Watch.

Good Alternatives/Yellow: Consumers are encouraged to purchase seafood in this category, as they are better choices than seafood from the Avoid category. However, there are some concerns with how this species is farmed and thus it does not demonstrate all of the qualities of sustainable aquaculture as defined by Seafood Watch.

Avoid/Red: Consumers are encouraged to avoid seafood from this category, at least for now. Species in this category do not demonstrate enough qualities to be defined as sustainable by Seafood Watch.

CRITERION 1: USE OF MARINE RESOURCES

Guiding Principle: To conserve ocean resources and provide net protein gains for society, aquaculture operations should use less wild-caught fish (in the form of fish meal and fish oil) than they produce in the form of edible marine fish protein

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Feed Use Components to Evaluate

A) Yield Rate: Amount of wild-caught fish (excluding fishery by-products) used to create fish meal and fish oil (ton/ton):

- Wild Fish: Fish Meal; Enter ratio = **4.5** [i.e. value = 4.5:1 from Tyedmers (2000)[4]]
- Wild Fish: Fish Oil; Enter ratio: **8.3** [i.e. value = 8.3:1 from Tyedmers (2000)]

B) Inclusion rate of fish meal, fish oil, and other marine resources in feed (%):

- Fish Meal; Enter % = **.202**
- Fish Oil; Enter % = **.073**

C) Efficiency of Feed Use: Known or estimated average economic Feed Conversion Ratio (FCR = dry feed:wet fish) in grow-out operations:

- Enter FCR here = **1.3**

Wild Input: Farmed Output Ratio (WI:FO)

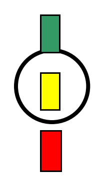
Calculate and enter the larger of two resultant values:

- Meal: [Yield Rate]$_{meal}$ x [Inclusion rate]$_{meal}$ x [FCR] = **1.2**
- Oil: [Yield Rate]$_{oil}$ x [Inclusion rate]$_{oil}$ x [FCR] = **.8**
- WI:FO = **1.2:1**

Primary Factor (WI:FO)

Estimated wild fish used to produce farmed fish (ton/ton, from above):

- Low Use of Marine Resources (WI:FO = 0 - 1.1) OR supplemental feed not used
- **Moderate Use of Marine Resources (WI:FO = 1.1 - 2.0)**
- Extensive Use of Marine Resources (WI:FO > 2.0)



[4] Tyedmers (2000): Salmon and sustainability: The biophysical cost of producing salmon through the commercial salmon fishery and the intensive salmon culture industry. PhD Thesis. The University of British Columbia. 272 pp.

Secondary Factors

Stock status of the reduction fishery used for feed for the farmed species:

- At or above B_{MSY} (> 100%)
- Moderately below B_{MSY} (50 - 100%) OR **Unknown**
- Substantially below B_{MSY} (e.g. < 50%) OR Overfished OR Overfishing is occurring OR fishery is unregulated
- Not applicable because supplemental feed not used

Source of stock for the farmed species:

- **Stock from closed life cycle hatchery** OR wild caught and intensity of collection clearly does not result in depletion of brood stock, wild juveniles or associated non-target organisms
- Wild caught and collection has the potential to impact brood stock, wild juveniles or associated non-target organisms
- Wild caught and intensity of collection clearly results in depletion of brood stock, wild juveniles, or associated non-target organisms

Evaluation Guidelines

Use of marine resources is "**Low**" when WI:FO is between 0.0 and 1.1.

Use of marine resources is "**Moderate**" when WI:FO is between 1.1 and 2.0.

Use of marine resources is "**Extensive**" when:

1. WI:FO is greater than 2.0
2. Source of stock for the farmed species is ranked red
3. Stock status of the reduction fishery is ranked red

Use of marine resources is deemed to be a **Critical Conservation Concern** and a species is ranked **Avoid**, regardless of other criteria, if:

1. WI:FO is greater than 2.0 AND the source of seed stock is ranked red.
2. WI:FO is greater than 2.0 AND the stock status of the reduction fishery is ranked red.

Conservation Concern: Use of Marine Resources

Low (Low Use of Marine Resources)

Moderate (Moderate Use of Marine Resources)

High (Extensive Use of Marine Resources)

Critical Use of Marine Resources

CRITERION 2: RISK OF ESCAPED FISH TO WILD STOCKS

Guiding Principle: Sustainable aquaculture operations pose no substantial risk of deleterious effects to wild fish stocks through the escape of farmed fish.

Primary Factors to evaluate

Evidence that farmed fish regularly escape to the surrounding environment

- **Rarely if system is open** OR never because system is closed
- Infrequently if system is open OR Unknown
- Regularly and often in open systems

Status of escaping farmed fish to the surrounding environment

- **Native and genetically and ecologically similar to wild stocks** OR **survival and/or reproductive capability of escaping farmed species is known to be naturally zero** or is zero because of sterility, polyploidy or similar technologies
- Non-native but historically widely established OR Unknown
- Non-native (including genetically modified organisms) and not yet fully established OR native and genetically or ecologically distinct from wild stocks

Secondary Factors to evaluate

Where escaping fish is non-native – Evidence of the establishment of self-sustaining feral stocks

- **Studies show no evidence of establishment to date**
- Establishment is probable on theoretical grounds OR Unknown
- Empirical evidence of establishment

Where escaping fish is native – Evidence of genetic introgression through successful crossbreeding

- **Studies show no evidence of introgression to date**
- Introgression is likely on theoretical grounds OR Unknown
- Empirical evidence of introgression

Evidence of spawning disruption of wild fish

- **Studies show no evidence of spawning disruption to date**
- Spawning disruption is likely on theoretical grounds OR Unknown
- Empirical evidence of spawning disruption

Evidence of competition with wild fish for limiting resources or habitats

- **Studies show no evidence of competition to date**
- Competition is likely on theoretical grounds OR Unknown
- Empirical evidence of competition

Stock status of affected wild fish

- At or above (> 100%) B_{MSY} OR no affected wild fish
- Moderately below (50 – 100%) B_{MSY} OR **Unknown**
- Substantially below B_{MSY} (< 50%) OR Overfished OR "endangered", "threatened" or "protected" under state, federal or international law

Evaluation Guidelines

A "**Minor Risk**" occurs when a species:

1) Never escapes because system is closed
2) Rarely escapes AND is native and genetically/ecologically similar.
3) Infrequently escapes AND survival is known to be nil.

A "**Moderate Risk**" occurs when the species:

1) Infrequently escapes AND is non-native and not yet fully established AND there is no evidence to date of negative interactions.
2) Regularly escapes AND native and genetically and ecologically similar to wild stocks or survival is known to be nil.
3) Is non-native but historically widely established.

A "**Severe Risk**" occurs when:

1) The two primary factors rank red AND one or more additional factor ranks red.

Risk of escapes is deemed to be a **Critical Conservation Concern** and a species is ranked **Avoid**, regardless of other criteria, when:

1) Escapes rank a "severe risk" AND the status of the affected wild fish also ranks red.

Conservation Concern: Risk of Escaped Fish to Wild Stocks	
Low (Minor Risk)	■
Moderate (Moderate Risk)	■
High (Severe Risk)	■
Critical Risk	■

CRITERION 3: RISK OF DISEASE AND PARASITE TRANSFER TO WILD STOCKS

Guiding Principle: Sustainable aquaculture operations pose little risk of deleterious effects to wild fish stocks through the amplification, retransmission or introduction of disease or parasites.

Primary Factors to evaluate

Risk of amplification and retransmission of disease or parasites to wild stocks

- **Studies show no evidence of amplification or retransmission to date**
- Likely risk of amplification or transmission on theoretical grounds OR Unknown
- Empirical evidence of amplification or retransmission

Risk of species introductions or translocations of novel disease/parasites to wild stocks

- **Studies show no evidence of introductions or translocations to date**
- Likely risk of introductions or translocations on theoretical grounds OR Unknown
- Empirical evidence of introductions or translocations

Secondary Factors to evaluate

Bio-safety risks inherent in operations

- Low risk: Closed systems with controls on effluent release
- **Moderate risk: Infrequently discharged ponds or raceways OR Unknown**
- High risk: Frequent water exchange OR open systems with water exchange to outside environment (e.g. nets, pens or cages)

Stock status of potentially affected wild fish

- At or above (> 100%) B_{MSY} OR no affected wild fish
- Moderately below (50 – 100%) B_{MSY} OR **Unknown**
- Substantially below B_{MSY} (< 50%) OR Overfished OR “endangered”, “threatened” or “protected” under state, federal or international law

Evaluation Guidelines

Risk of disease transfer is deemed "**Minor**" if:

1) Neither primary factor ranks red AND both secondary factors rank green.
2) Both primary factors rank green AND neither secondary factor ranks red

Risk of disease transfer is deemed to be **"Moderate"** if the ranks of the primary and secondary factors "average" to yellow.

Risk of disease transfer is deemed to be "**Severe**" if:

1) Either primary factor ranks red AND bio-safety risks are low or moderate.
2) Both primary factors rank yellow AND bio-safety risks are high AND stock status of the wild fish does not rank green.

Risk of disease transfer is deemed to be a **Critical Conservation Concern** and a species is ranked **Avoid** regardless of other criteria, if either primary factor ranks red AND stock status of the wild fish also ranks red.

Conservation Concern: Risk of Disease Transfer to Wild Stocks	
Low (Minor Risk)	
Moderate (Moderate Risk)	
High (Severe Risk)	
Critical Risk	

CRITERION 4: RISK OF POLLUTION AND HABITAT EFFECTS

Guiding Principle: Sustainable aquaculture operations employ methods to treat and reduce the discharge of organic effluent and other potential contaminants so that the resulting discharge and other habitat impacts do not adversely affect the integrity and function of the surrounding ecosystem.

Primary Factors to evaluate

PART A: Effluent Effects

Effluent water treatment

- **Effluent water substantially treated before discharge (e.g. recirculating system, settling ponds, or reconstructed wetlands)** OR polyculture and integrated aquaculture used to recycle nutrients in open systems OR treatment not necessary because supplemental feed is not used
- Effluent water partially treated before discharge (e.g. infrequently flushed ponds)
- Effluent water not treated before discharge (e.g. open nets, pens or cages)

Evidence of substantial local (within 2 x the diameter of the site) effluent effects (including altered benthic communities, presence of signature species, modified redox potential, etc)

- Studies show no evidence of negative effects to date
- Likely risk of negative effects on theoretical grounds OR **Unknown**
- Empirical evidence of local effluent effects

Evidence of regional effluent effects (including harmful algal blooms, altered nutrient budgets, etc)

- Studies show no evidence of negative effects to date
- Likely risk of negative effects on theoretical grounds OR **Unknown**
- Empirical evidence of regional effluent effects

Extent of local or regional effluent effects

- **Effects are in compliance with set standards**
- Effects infrequently exceed set standards
- Effects regularly exceed set standards

Part B: Habitat Effects

Potential to impact habitats: Location

- **Operations in areas of low ecological sensitivity (e.g. land that is less susceptible to degradation, such as formerly used agriculture land or land previously developed)**
- Operations in areas of moderate sensitivity (e.g. coastal and near-shore waters, rocky intertidal or subtidal zones, river or stream shorelines, offshore waters)
- Operations in areas of high ecological sensitivity (e.g. coastal wetlands, mangroves)

Potential to impact habitats: Extent of Operations

- **Low density of fish/site or sites/area relative to flushing rate and carrying capacity in open systems** OR closed systems
- Moderate densities of fish/site or sites/area relative to flushing rate and carrying capacity for open systems
- High density of fish/site or sites/area relative to flushing rate and carrying capacity for open systems

Evaluation Guidelines

Risk of pollution/habitat effects is "**Low**" if three or more factors rank green and none of the other factors are red.

Risk of pollution/habitat effects is "**Moderate**" if factors "average" to yellow.

Risk of pollution/habitat effects is "**High**" if three or more factors rank red.

No combination of ranks can result in a **Critical Conservation Concern** for Pollution and Habitat Effects.

Conservation Concern: Risk of Pollution and Habitat Effects

Low (Low Risk)

Moderate (Moderate Risk)

High (High Risk)

CRITERION 5: EFFECTIVENESS OF THE MANAGEMENT REGIME

Guiding Principle: The management regime of sustainable aquaculture operations respects all local, national and international laws and utilizes a precautionary approach, which favors the conservation of the environment, for daily operations and industry expansion.

Primary Factors to evaluate

Demonstrated application of existing federal, state and local laws to current aquaculture operations

- **Yes, federal, state and local laws are applied**
- Yes but concerns exist about effectiveness of laws or their application
- Laws not applied OR laws applied but clearly not effective

Use of licensing to control the location (siting), number, size and stocking density of farms

- **Yes and deemed effective**
- Yes but concerns exist about effectiveness
- No licensing OR licensing used but clearly not effective

Existence and effectiveness of "better management practices" for aquaculture operations, especially to reduce escaped fish

- **Exist and deemed effective**
- Exist but effectiveness is under debate OR Unknown
- Do not exist OR exist but clearly not effective

Existence and effectiveness of measures to prevent disease and to treat those outbreaks that do occur (e.g. vaccine program, pest management practices, fallowing of pens, retaining diseased water, etc.)

- **Exist and deemed effective**
- Exist but effectiveness is under debate OR Unknown
- Do not exist OR exist but clearly not effective

Existence of regulations for therapeutants, including their release into the environment, such as antibiotics, biocides, and herbicides

- Exist and deemed effective OR **no therapeutants used**
- Exist but effectiveness is under debate, or Unknown
- Not regulated OR poorly regulated and/or enforced

Use and effect of predator controls (e.g. for birds and marine mammals) in farming operations

- Predator controls are not used OR **predator deterrents are used but are benign**
- Predator controls used with limited mortality or displacement effects
- Predator controls used with high mortality or displacement effects

Existence and effectiveness of policies and incentives, utilizing a precautionary approach (including ecosystem studies of potential cumulative impacts) against irreversible risks, to guide expansion of the aquaculture industry

- Exist and are deemed effective
- **Exist but effectiveness is under debate**
- Do not exist OR exist but are clearly ineffective

Evaluation Guidelines

Management is "**Highly Effective**" if four or more factors rank green and none of the other factors rank red.

Management is "**Moderately Effective**" if the factors "average" to yellow.

Management is deemed to be "**Ineffective**" if three or more factors rank red.

No combination of factors can result in a **Critical Conservation Concern** for Effectiveness of Management.

Conservation Concern: Effectiveness of the Management Regime

Low (Highly Effective)

Moderate (Moderately Effective)

High (Ineffective)

Overall Seafood Recommendation

Overall Guiding Principle: Sustainable farm-raised seafood is grown and harvested in ways can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

Evaluation Guidelines

A species receives a recommendation of "**Best Choice**" if:

1) It has three or more green criteria and the remaining criteria are not red.

A species receives a recommendation of "**Good Alternative**" if:

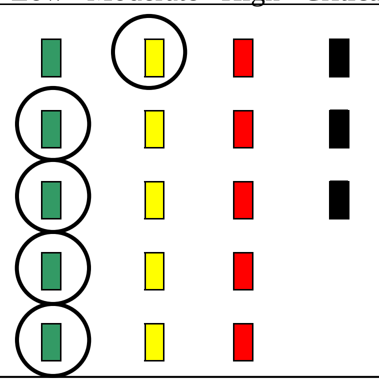
1) Criteria "average" to yellow.
2) There are four green criteria and one red criterion.

A species receives a recommendation of "**Avoid**" if:

1) It has a total of two or more red criteria.
2) It has one or more Critical Conservation Concerns.

Summary of Criteria Ranks ***Conservation Concern***

Sustainability Criteria	Low Moderate High Critical
Use of Marine Resources	
Risk of Escapes to Wild Stocks	
Risk of Disease/Parasite Transfer to Wild Stocks	
Risk of Pollution and Habitat Effects	
Effectiveness of Management	

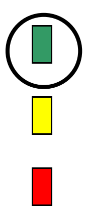


Overall Seafood Recommendation

Best Choice

Good Alternative

Avoid



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